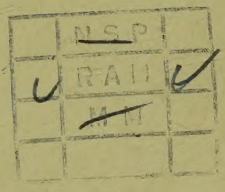
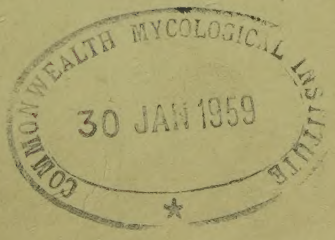
ANNUAL REPORT

of the

WEST AFRICAN COCOA RESEARCH INSTITUTE

1957-58





A POISONOUS INSECTICIDAL
SOLUTION HAS BEEN USED
IN BINDING THIS BOOK.

Broadcasting Fertilizer in Amelonado Cacao

ANNUAL REPORT

of the

WEST AFRICAN COCOA RESEARCH INSTITUTE

1957-58

Price 5/-

Published on behalf of the West African Cocoa Research Institute by the
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MANAGING COMMITTEE

At 31st March 1958

CHAIRMAN

*†Acting Chief Secretary, West African Inter-Territorial Secretariat.

MEMBERS

*†Director, West African Cocoa Research Institute.

Chairman, Ghana Cocoa Marketing Board.

Mr B. E. Dwira, member of the Ghana Cocoa Marketing Board.

Mr Osei Bonsu, Ghana.

*Principal Assistant Secretary, Ministry of Agriculture, Ghana.

*†Director of Agriculture, Ghana.

Permanent Secretary, Ministry of Research and Information, Federation of Nigeria.

†Director of Agricultural Research, Federation of Nigeria.

Permanent Secretary, Ministry of Agriculture and Natural Resources, Western Region, Nigeria.

†Director of Agriculture, Western Region, Nigeria.

Rev. E. T. Latunde, O.B.E., Nigeria.

†Director of Agriculture, Sierra Leone.

CO-OPTED MEMBERS (non-voting)

†Director of Agriculture, Eastern Region, Nigeria.

†Deputy Director of Agriculture (Cocoa Industry), Ghana.

†Principal Agricultural Officer, Southern Cameroons.

†Secretary for West African Agricultural and Forestry Research

Manager, Messrs Cadbury & Fry, Ghana.

Manager, Messrs Rowntree-Fry-Cadbury, Nigeria.

†Deputy Director, West African Cocoa Research Institute.

†Deputy Director (Nigeria), WACRI Sub-Station, Ibadan, Nigeria.

Secretary, West African Cocoa Research Institute.

* Members of General Purposes Sub-Committee
† Members of Technical Sub-Committee

SENIOR STAFF

At 31st March 1958

TAFO STATION

Director	J. Lamb, O.B.E., M.SC., F.R.I.C., A.I.C.T.A.
Deputy Director	*C. G. Johnson, PH.D., D.SC., F.R.E.S., M.INST.BIOL.
Scientific Assistant to Director	G. A. Jones, B.SC.
Secretary	H. L. Pugh, A.C.C.S.
Assistant Accountant	J. N. A. Hyde, A.C.C.S., A.A.I.A.
Office Assistant/Librarian	Mrs J. Nicholas (Temporary)
Entomologists	*C. G. Johnson
	P. F. Entwistle, B.SC., A.R.C.S.
Plant Pathologists	J. W. Blencowe, PH.D.
	A. L. Wharton, B.SC., DIP.AG.SCI., D.T.A.
	A. A. F. Brunt, B.SC.
	A. Attafuah (Assistant Specialist)
Botanist	R. G. Hurd, PH.D., M.INST.BIOL.
Plant Breeder	D. R. Glendinning, B.SC.
Chemists	*R. H. Kenten, B.SC., A.R.I.C.
	R. K. Cunningham, B.SC.
Agronomists	R. W. Smith, B.SC.
	J. F. Longworth, M.SC.
Statistician	C. de Jonge, L.I. (WAG.), A.R.N.S.A.S.
Laboratory Technicians (Electronics)	*A. J. H. Arnold, A.S.E.
(Spectrography)	J. C. Burridge, M.A., B.SC.
Plantations Manager	H. W. S. Allison
Guide-Demonstrator	F. E. Decker
Station Manager	S. E. Ntim Kwafo
Maintenance Engineer	A. Maddison
Works Superintendent	E. K. Berko

IBADAN SUB-STATION

Deputy Director (Nigeria)	T. W. Tinsley, PH.D., M.INST.BIOL.
Entomologists	R. G. Donald, B.SC., A.I.C.T.A.
	C. K. H. Martini, PH.D.
Plant Pathologists	J. M. Thresh, B.SC., A.R.C.S.
	D. Kay, B.SC., M.INST.BIOL.
	†E. C. Hislop, B.SC., D.P.P.

* Seconded from Rothamsted Experimental Station
† Seconded from Colonial Pesticides Research Unit, Arusha, Tanganyika

ADMINISTRATION

Managing Committee

Meetings of the Managing Committee were held at Tafo on the 15th August 1957 and the 12th February 1958. The Technical Sub-Committee met at Tafo on the 14th August 1957 and at Ibadan on the 3rd and 4th January 1958.

Mr S. J. E. Southgate, who was Chief Secretary of the West African Inter-Territorial Secretariat and Chairman of the Institute's Managing Committee, left West Africa in December 1957 to take up an appointment in the United Kingdom. Mr L. G. Heptinstall became Acting Chief Secretary of the West African Inter-Territorial Secretariat, and took the Chair at the meeting of the Managing Committee held in February 1958.

The Government of Ghana appointed Mr Osei Bonsu as a member of the Committee, in place of Mr E. O. Asafu-Adjaye. Mr Bonsu attended the February meeting of the Committee.

Finance

The decision of the Managing Committee to reorganise the Institute's accounting system to conform to commercial practice was mentioned in the previous Annual Report. An Assistant Accountant, who, it is hoped, will ultimately take complete charge of the accounts, has since been appointed, and he is proceeding with the preliminary stages of the change-over. A Senior Accountant has been engaged on short-term contract to supervise the introduction of the new system, and he is expected to assume duties in June 1958.

The Balance Sheet as at 31st March 1958 is shown at the end of the report.

Staff

Senior Staff

There has been a further improvement in the Senior Staff position during the year, particularly at the Ibadan Sub-Station. Taking into account the officers still in training in the United Kingdom, most of whom are due to join the Institute during 1958, and appointments which are being negotiated, there remain only four vacancies in the establishment for senior staff.

At Tafo Dr J. W. Blencowe arrived in July to take up his appointment as Head of the Plant Pathology Division, and another Pathologist, Mr A. A. F. Brunt, arrived in September. Dr Rohan, formerly Head of the Chemistry Division, has resigned, and his place has been taken by Mr R. H. Kenten, who arrived at Tafo in December, on

secondment from Rothamsted Experimental Station. We are also indebted to Rothamsted for the secondment of Mr A. J. H. Arnold, who came out in August to set up a workshop for the maintenance of laboratory equipment and the construction of special pieces of apparatus.

The main laboratory block at Tafo is being extended to accommodate a spectrographic laboratory, and Mr J. C. Burridge joined the Institute in October to take charge of this laboratory. A long-felt gap was filled when Mr C. de Jonge assumed duties as Statistician in March 1958. Two agronomists, Mr R. W. Smith and Mr J. F. Longworth, arrived at Tafo in December after a period of training at East Malling Research Station.

Following the decision of the Managing Committee to revise the Institute's accounting system, Mr J. N. A. Hyde was appointed as Assistant Accountant and assumed duties in December. The Maintenance Division has been taken over by Mr A. Maddison, who arrived in April, and Mr E. K. Berko, formerly a member of the Junior Staff, was promoted to the post of Works Superintendent within this Division in August.

Miss E. Margaret Holden and Dr P. W. Arnold, who were on secondment from Rothamsted Experimental Station, have returned to their substantive posts. Mr R. J. Benstead, who has been at WACRI since its foundation, has retired. Mr Benstead has played a considerable part in the development of the Institute, and his wide experience of local conditions will be greatly missed. Mr D. J. Taylor has resigned to take up an appointment at the Waite Agricultural Research Institute in Australia, while Mr A. D. McKelvie has left to join the Plant Breeding Institute at Cambridge. The Office Assistant/Librarian, Miss A. Bryan, has also resigned, and pending a permanent appointment her place has been taken by Mrs J. Nicholas.

At the Ibadan Sub-Station Dr T. W. Tinsley took up his appointment as Deputy Director (Nigeria) in July. Dr C. K. H. Martini joined the staff as Virus Entomologist in September, while Mr D. Kay assumed duties as Mycologist in April 1957. A team of specialists is being seconded from the Colonial Pesticides Research Unit, Arusha, Tanganyika, to form a West African Fungicides Research Unit which will be attached to the Sub-Station, and will work initially on the fungicidal control of black-pod disease. Mr E. C. Hislop, the Mycologist of the Unit, arrived at Ibadan in February.

A third WACRI scholarship has been awarded to Mr D. Acquaye, a Ghanaian working for a Ph.D. degree in the Department of Soil Science, Aberdeen University. The other scholars, Mr E. J. A. Asomaning studying at Yale University, and Mr V. Ammah-Attoh at the University of London, are making good progress.

Junior Staff

The Junior Staff position has remained satisfactory. Mr B. A. Bentum has returned to the Institute after following a three-year course at the Agricultural Training Centre, Kumasi, and he has been appointed to a pensionable post as Technical Assistant. Mr W. A. Sasu, an Assistant in the Station Management Division, has been awarded a four-month Trade Union Scholarship to follow a special course on Trade Unionism in Israel.

The number of daily-rated employees has remained at about 640.

A force of sixteen police constables with four N.C.O.s has been seconded to the Institute from the Ghana Police Force, primarily to protect the experimental crop.

Publications

The following papers, giving accounts of work done at the Institute, have been published during the year.

Attafuah, A. and Tinsley, T. W.: 'Virus diseases of *Adansonia digitata* L. (Bombacaceae) and their relation to cacao in Ghana'. *Ann. appl. Biol.*, **46**, pp. 20–22, 1958.

Cornwell, P. B.: 'A preliminary investigation into the uptake and translocation of Phosphorus-32 in *Theobroma cacao* L.'. *Trop. Agriculture, Trin.*, **34**, pp. 117–132, 1957.

—— : 'An investigation into the effect of cultural conditions on populations of the vector of virus diseases of cacao in Ghana with an evaluation of seasonal population trends'. *Bull. ent. Res.*, **48**, pp. 375–396, 1957.

Deighton, F. C. and Tinsley, T. W.: 'Notes on some plant virus diseases to be found in Sierra Leone and Ghana'. *J. W. Afr. Sci. Ass.* (in the press).

Holden, E. M.: 'An investigation on polyphenolic compounds of the cacao leaf in connection with a chemical method for detecting virus infection'. *J. Sci. Fd. Agric.*, **8**, pp. 553–561, 1958.

Knight, R. and Tinsley, T. W.: 'Some histological observations on virus-infected *Theobroma cacao* L.'. *Ann. appl. Biol.*, **46**, pp. 7–10, 1958.

McKelvie, A. D.: 'The polythene sheet method of rooting cacao cuttings'. *Trop. Agriculture, Trin.*, **34**, pp. 260–265, 1958.

Rohan, T. A.: 'The processing of raw cocoa. I. Small-scale fermentation'. *J. Sci. Fd. Agric.*, **9**, pp. 104–111, 1958.

Tinsley, T. W. and Wharton, A. L.: 'Studies on the host ranges of viruses from *Theobroma cacao* L.'. *Ann. appl. Biol.*, **46**, pp. 1–6, 1958.

A fourth Technical Bulletin on 'The control of cacao swollen-shoot disease in West Africa. A review of the present situation' by Mr J. M. Thresh is in the press.

Conferences

Mr J. Lamb, Director, and Dr T. A. Rohan flew to the United Kingdom in September 1957 to attend the London Cocoa Conference. Several other members of the staff who were on leave at the time, and some former members of the Institute's staff, also attended the conference, and the following papers were presented.

Donald, R. G.: 'A capsid control experiment in the Western Region of Nigeria'.

Glendinning, D. R.: 'The performance of the introductions and hybrids in WACRI trials'.

Lister, R. M. and Thresh, J. M.: 'The history and control of cocoa swollen-shoot disease in Nigeria'.

McKelvie, A. D.: 'Rooting cocoa cuttings under polythene'.

Posnette, A. F. and Entwistle, H. M.: 'The pollination of cocoa flowers'.

Rohan, T. A.: 'Polyphenols and quality in West African Amelonado cocoa'.

—— : 'Observations on the fermentation of West African Amelonado Cocoa'.

Taylor, D. J.: 'Pest control research at WACRI'.

Several members of the staff from Tafo and Ibadan attended the Second Conference organised by the West African Science Association at the University College of Ghana in March.

Visitors

During the year the Institute has been honoured by visits from His Excellency the Governor-General of Ghana; the Minister of Agriculture, Ghana; the Minister of Agriculture and Natural Resources, Western Region, Nigeria; and the Commissioner of the Eastern Region, Ghana. His excellency the Governor-General of the Federation of Nigeria and Lady Robertson have paid an informal visit to the Ibadan Sub-Station. Sir Ian Maclennan, the United Kingdom High Commissioner in Ghana, and Mr E. W. T. Gill, the Canadian High Commissioner, have also visited Tafo, and Mr C. J. M. Alport, Permanent Under-Secretary of the United Kingdom Commonwealth Relations Office spent a day at the Institute during his tour of Ghana in April 1957.

Delegates attending the FAO Cocoa Study Group meeting at Ibadan in 1957 subsequently paid a short visit to Tafo. Several officers of the Food and Agriculture Organisation have been welcomed, including Mr A. H. Boerma, Dr A. Viton and Dr C. A. Krug. Among the visitors from other scientific organisations in Africa have been Dr Risbec, Scientific Secretary of the Inter-African Phytosanitary Commission; Mr J. Guillotteau, Director of the Inter-African Bureau for Soils and Rural Economy; and Messrs K. Wilson Jones of the Colonial Pesticides Research Committee and K. S. Hocking of the Colonial Insecticides Research Unit.

Close contact has been maintained with the University Colleges of Ghana and Ibadan, and we were pleased to receive a visit from the Principal at Legon, Dr R. H. Stoughton. We have also received several visits from senior officers of other West African research organisations and Departments of Agriculture.

Dr V. Eastop of the British Museum spent several months at Tafo studying aphids and white flies.

Among other visitors to the Institute are included Mr David Owen, Chairman of the United Nations Technical Assistance Board; Professor W. A. Lewis, Economic Adviser to the Prime Minister of Ghana; Commander Sir Robert Jackson, Chairman of the Development Commission; Lieutenant-General Sir C. G. Packard, Military Adviser to the West African Governments; Mr D. Rhind of the Colonial Office, London; Mr John Cadbury of Bournville; Mr D. H. Joss of the Cocoa, Chocolate and Confectionery Alliance; Mr O. J. Voelcker, a former Director of WACRI; Mr R. H. Pinder of the ICA Mission in Ghana; and members of the Western Region Cocoa Marketing Board, Nigeria.

Visits to the Ibadan Sub-Station have increased considerably. The visitors during the year have included Mr G. W. Nye, Agricultural Adviser to the Secretary of State for the Colonies, London; Sayed Hassan Mitwakil, Assistant Director of Agriculture, Sudan; Professor E. T. C. Spooner of the London School of Hygiene and Tropical Medicine; Mr A. G. Simpson, Acting Permanent Secretary to the Ministry of Agriculture and Natural Resources, Sierra Leone; and Professor Patrick Collard of the University College, Ibadan.

Station Management and Maintenance

During the year the former Management Division was rearranged into two divisions. The Maintenance Division is now responsible for the construction of new buildings, and for the maintenance of existing buildings, roads, vehicles and the water works, while the Station Management Division is responsible for the general upkeep of the station, including sanitation, furniture and food production.

Buildings

At Tafo six new bungalows have been built in the Residential Area, and work has started on the construction of a Police Barracks. The main laboratory block is being extended, principally to accommodate the spectrographic laboratory. All fermentation and drying is now carried out centrally, and a new fermenting and drying shed is under construction. Workshop facilities are being improved and extensive renovations are under way. All buildings were re-wired in preparation for the changeover to AC electricity supply which took place in January 1958. Emergency power generators have been installed in case of failure of the supply from Koforidua. A considerable programme of road improvements has been started.

At Ibadan work has started on the erection of two additional Senior Staff houses. The lack of Junior Staff quarters presents some difficulties, and it is hoped that progress will be made with these during the coming year.

Water supplies

The consumption of water has increased considerably, mean daily consumption varying between 21,237 gallons in April and 41,770 gallons in January. The latter figure represents a marked increase over the highest figure previously recorded. The Department of Rural Water Development has started work on a scheme to provide potable water to the neighbouring villages from the WACRI reservoir. It is hoped that this will substantially reduce the consumption of water from the WACRI waterworks. The rainfall recorded at the waterworks varied from 1.67 in. in February 1958 to 14.00 in. in July 1957, with a total for the period under review of 71.0 in., on 171 wet days. There were only two days during the year when the intake to the impound area was negligible.

Production of vegetables

The old site of the vegetable garden has been abandoned, and a new garden started. The supply of green vegetables, rice and maize was maintained throughout the year.

Cocoa Production

A total of 111,314 lb. of cocoa has been sold during the year, representing a revenue of nearly £6,800. This yield shows an increase of 29,593 lb. over that of the previous year. For the whole station, only 3.4 per cent. of the pods harvested were discarded as unfit for fermentation.

Table 1

*Yield of recorded plots, Old Station**

Date of picking	Total pods Harvested	Total pods Discarded	% Pods discarded	Pods fermented	Wet wt. of beans (lb.)	Dry wt. of beans (lb.)	% Dry to wet weight	Pods per lb. dry cocoa	Pods issued for expts.
1957									
May 6–10	5,248	300	5.7	1,805	326.9	136.25	41.68	13.2	3,143
,, 13–17	2,784	269	9.7	2,515	455.9	190.22	41.72	13.2	—
June 24–26	4,768	430	9.0	4,338	531.8	221.94	41.73	19.5	—
Aug. 12–16	2,198	282	12.8	1,916	382.9	159.70	41.71	12.0	—
Total Minor Crop	14,998	1,281	8.5	10,574	1,697.5	708.11	41.71	14.9	3,143
Sept. 2–10	6,976	442	6.3	6,534	1,306.8	544.90	41.70	12.0	—
,, 17–25	11,010	1,650	15.0	9,360	1,940.0	808.90	41.70	11.6	—
,, 30–Oct. 8	43,301	5,104	11.8	38,197	7,652.6	3,186.83	41.64	12.0	—
Oct. 14–22	65,719	6,914	10.5	58,805	11,638.4	4,853.30	41.70	12.1	—
,, 24–31	30,820	2,995	9.6	27,865	5,573.0	2,324.85	41,72	12.0	—
Nov. 1– 8	29,346	3,485	11.9	25,861	5,172.0	2,152.60	41.62	12.0	—
,, 11–28	57,097	4,684	8.2	52,413	10,482.6	4,371.16	41.70	12.0	—
Dec. 4–Jan. 3	98,265	8,585	8.7	89,680	17,895.8	7,462.06	41.70	12.0	—
1958									
Jan. 8–18	22,575	3,471	15.4	19,104	3,820.8	1,591.16	41.64	12.0	—
Total Main Crop	365,109	37,290	10.2	327,819	65,482.0	27,295.76	41.68	12.0	—
1957–58	380,107	38,571	10.1	338,393	67,179.5	28,003.87	41.69	12.1	3,143
1956–57	419,848	13,971	3.3	393,952	84,859.5	35,975.89	42.39	11.0	11,925

* 63.69 acres of Amelonado cacao

On the recorded plots of the Old Station the yield of dry cocoa per acre was lower than that of the previous year, largely due to an increase in discarded pods because of infrequent harvesting of these plots. Details of this year's crop are given in Table 1, and a comparison with previous yield data in Table 2, where an assessed weight for pods issued as seed has been included.

TABLE 2

*Comparative yield data from recorded plots, Old Station**

	Pods harvested	*Pods discarded* (%)	*Total wet weight of beans (lb.)*	*Dry to wet weight* (%)	*Pods per lb. dry cocoa*	*Yield per acre (lb.)*
1957–58 ..	380,107	10.1	67,808	41.7	12.1	443.8
1956–57 ..	419,848	3.3	86,847	42.7	11.0	581.9
20-year mean	507,870	11.0	95,863	40.7	11.5	611.9

* 63.69 acres of Amelonado cacao.

Yield distribution in recorded quarter-acre plots is shown in Table 3. The modal class has fallen to the 401–600 lb. per acre class.

TABLE 3

Distribution of yield between quarter-acre plots

Yield class (lb. per acre)	*Percentage of plots in each class*			
	1954–55	1955–56	1956–57	1957–58
0– 200	17.8	12.5	7.6	13.8
201– 400	39.3	32.6	23.2	31.7
401– 600	30.4	33.9	25.4	34.8
601– 800	10.3	15.2	26.8	15.6
801–1,000	1.8	5.4	10.3	3.6
1,001–1,200	0.4	0.4	6.3	—
1,201–1,400	—	—	0.4	—
1,401–1,600	—	—	—	0.5
Highest plot yield	1,105.0	1,058.4	1,274.4	1,596.8
Lowest „ „	nil	nil	8.0	nil

Seed Distribution

A total of 46,950 F3 Upper-Amazon pods were sent to Nigeria and the Cameroons as seed.

Swollen-Shoot Disease Incidence

Swollen-shoot disease control at the Institute has been reorganised and placed under the technical supervision of the Pathology Division. All cacao trees are inspected monthly and diseased trees removed. Where experiments permit, trees in contact with diseased ones are also removed. Immediately following the reorganisation the number

of trees cut out was higher than usual, but the number has now fallen below the level of the average for the previous five years, and it is hoped that this improvement will continue.

Five hundred and fifty-five infected trees were removed from the Old Station, together with 83 suspects; 572 infected seedlings were discovered. On the Square Mile 5,300 trees were removed, of which 500 were trees in contact with infected ones.

Figures for 1957 *compared with* 20-*year means*

		Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
Highest Shade Maximum	20-year mean ..	91.4	93.8	93.1	93.8	92.3	89.1	87.0	86.5	88.0	89.8	90.5	90.6
	1957	91	95	93	94	95	89	87	87	87	89	91	90
Lowest Shade Maximum	20-year mean ..	58.9	91.9	66.0	66.5	66.9	66.1	66.0	65.3	66.9	66.8	65.6	62.6
	1957	52	64	67	67	69	68	67	69	69	67	68	68
Mean Relative Humidity	20-year mean ..	86.3	83.8	82.1	80.9	81.8	85.0	86.2	86.1	85.3	83.4	81.3	84.3
(09.00 GMT)	1957	83.6	83.1	80.9	81.7	82.5	85.6	88.8	87.4	86.8	83.4	82.0	84.9
Mean Relative Humidity	20-year mean ..	55.5	53.0	56.7	59.4	64.3	69.9	70.7	69.6	71.2	72.6	65.9	61.8
(15.00 GMT)	1957	52.0	51.6	57.7	64.1	70.3	77.8	79.1	73.0	75.9	72.7	67.6	63.5
Rainfall in inches	20-year mean ..	1.52	3.62	5.85	6.12	7.08	8.48	5.77	2.49	6.10	8.90	4.12	2.38
	1957	1.28	2.81	1.48	11.99	8.30	10.65	16.04	1.97	4.73	5.19	3.74	2.72
Number of Wet Days	20-year mean ..	3.6	7.0	11.7	11.3	14.0	18.8	14.1	13.1	14.8	18.7	10.9	6.2
	1957	5	6	9	15	18	23	23	18	18	19	13	8

Annual Rainfall figures (in inches) 1938–1957

1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	20-*Year Mean*
55.33	84.96	56.92	56.59	59.45	69.09	49.12	68.87	47.03	67.30	66.99	71.81	63.47	66.23	65.77	53.88	57.53	73.16	51.12	70.90	62.43

Monthly Rainfall (in inches) and Number of Wet Days, April 1957-*March* 1958

Month	*April*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Jan.*	*Feb.*	*March*
Rainfall in inches	11.99	8.30	10.65	16.04	1.97	4.73	5.19	3.74	2.72	1.97	3.00	6.64
Number of Wet Days	15	18	23	23	18	18	19	13	8	7	8	15

RESEARCH

In the **Plant Pathology** Division work has continued on the relative susceptibilities to virus infection of Amazon and Amelonado cacao varieties. Observations on coppiced cacao at WACRI have indicated a high incidence of masked virus infection in apparently healthy trees. In Nigeria further experiments are in progress to determine the ability of mild virus strains to protect cacao trees from the effects of more severe viruses.

From a study of the distribution of *Phytophthora* infections on pods it would appear unlikely that systemic infections are an important perennial source of black-pod disease, and spore-transmitted infections probably initiate the major epiphytotics. A satisfactory standard technique for infecting cacao pods in the laboratory is being developed. Observations on the incidence of black-pod disease on various cacao selections have indicated consistent differences in susceptibility.

In Nigeria an extensive series of experiments have been started on 'die-back' of cacao. A number of diseases affecting cacao in the Cameroons have been investigated.

The series of trials being carried out by the **Entomology** Division, in conjunction with the Department of Agriculture, on the control of mealybugs by destroying attendant ants are continuing. In the large-scale trial two dieldrin applications have been sufficient to reduce mealybug populations to very low levels for a period of over twelve months, up to which time no effects on swollen-shoot disease incidence were apparent. Following-up the results of the 1956 experiments on capsid control, endrin, aldrin, dieldrin and *gamma*-BHC have been included in further trials. Preliminary results suggest that endrin is extremely effective, and that *gamma*-BHC is more effective than aldrin. Dieldrin gave unsatisfactory results, and malathion, which was included in some of the tests, was also unsatisfactory at the dosages used. Increased incidence of pod miner appeared to be related to the use of routine sprays, especially of dieldrin. Pollination studies have shown no reduction in pollination rates following the use of insecticide sprays. Minor insect pests of cacao are receiving increasing attention.

In spacing trials of the **Agronomy** Division Amelonado cacao has again given the highest yield at $7\frac{1}{2} \times 7\frac{1}{2}$ ft. Conflicting results have been obtained from the pruning Trials.

Selections in the **Botany** Division trials have yielded well. One of the Amelonado-Upper Amazon crosses in the 9th Progeny Trial has given the equivalent of over 1,400 lb. dry cocoa per acre in its fourth year from planting. Data from the 2nd Albino Plot has indicated that

a substantial amount of natural pollination may occur across five or six rows of trees. This result may have considerable significance in the design of seed gardens.

Experiments on the uptake of phosphorus from the soil, using radio-active tracers, have shown that uptake tends to a maximum in June, thereafter falling to a minimum in March. There appeared to be no relation between the rate of uptake and the development of the crop. Studies on factors affecting yield have continued, and preliminary experiments have been carried out on the effect of gibberellic acid on the growth of cacao seedlings and cuttings.

Significant responses have been obtained by the **Chemistry** Division in the first year of a Shade and Manurial Trial on Amelonado cacao. In the control plots moderately-shaded unmanured cacao gave about 600 lb. dry cocoa per acre. The application of a mixture of NPK and Mg increased the yield to about 850 lb. per acre, while shade removal without manure gave about 1,000 lb. per acre. Shade removal combined with fertilizer application gave nearly 1,600 lb. per acre. A further series of trials with major and minor nutrients on Amelonado and Amazon cacao have been started.

Studies on the fermentation of West African cocoa have led to the development of a simplified technique involving the use of trays for both fermenting and drying. Preliminary results are encouraging. Work on the enzymic aspects of fermentation have continued. A germination inhibitor has been found in the pulp of cocoa beans.

TAFO STATION

EXPERIMENTAL AREAS

A–Agronomic Investigations

A 1–Upper-Amazon Seed Multiplication Plot.

A 2–Upper-Amazon Spacing and Pruning Experiment.

A 5–*Herrania* Plot.

A 7–Amelonado Source Experiment.

A 8, 9–Seedling Reserves.

A10–Establishment Experiment II—Comparison of Planted and Natural Shade.

A11–Amelonado Spacing Experiment.

A15–*Herrania* Bulking Area.

A16 to 18, 20 to 22–Seedling Reserves.

A23–Shade and Manurial Trial.

A24–Pruning and Fertilizer Trial.

B –Botanical Investigations

B 1–Clonal Collection.

B 2–Clonal Trial III—1956.

B 3–Progeny Trial IX—1954.

B 5{ Clonal Trial I—Ghana Selections. / Pod Disease Resistance Trial.

B 6–Cytogenetics Observation Plot.

B 7–Progeny Trial VIII—1952.

B 8–Albino Plot.

B 9–Clonal Trial II—Ghana Selections.

B10–Trinidad Introductions Area.

B11–*Theobroma* and *Herrania* spp. Area.

B17–Colombian Introductions Area.

B18–Proposed Progeny Trial Area.

B19–Seedling Growth Experiment.

B20–Plant Breeding Nursery.

B21–Propagators.

B22–Clonal Nursery.

B23–Early Bearing Experiment.

B24–New Planting Area.

B25–*Herrania* Bulking Area.

E–Entomological Investigations

E22–Ant Control Experiment.

E23, E24, E25} Effect of Insecticides on Pollination.

S–Soil-fertility Investigations

S 6–Establishment Experiment on Clear-felled land—different ground covers.

S 7–Soil Exposure Experiment.

S 8–Establishment on Exposed Soil.

S 9–Minor Element Deficiency Area.

S10–Copper Nutrition Experiment.

S11–Long-term experiment on degrees of shade and rates of fertilizers.

S12–Rates of N, P, K, Mg Experiment.

S13–2^4 N, P, K, Mg, Factorial Experiment on Amazons.

S14–Mulching and Ground Cover Experiment.

P–Pathological Investigations

P 2–Studies on Susceptibility to Black-pod Disease.

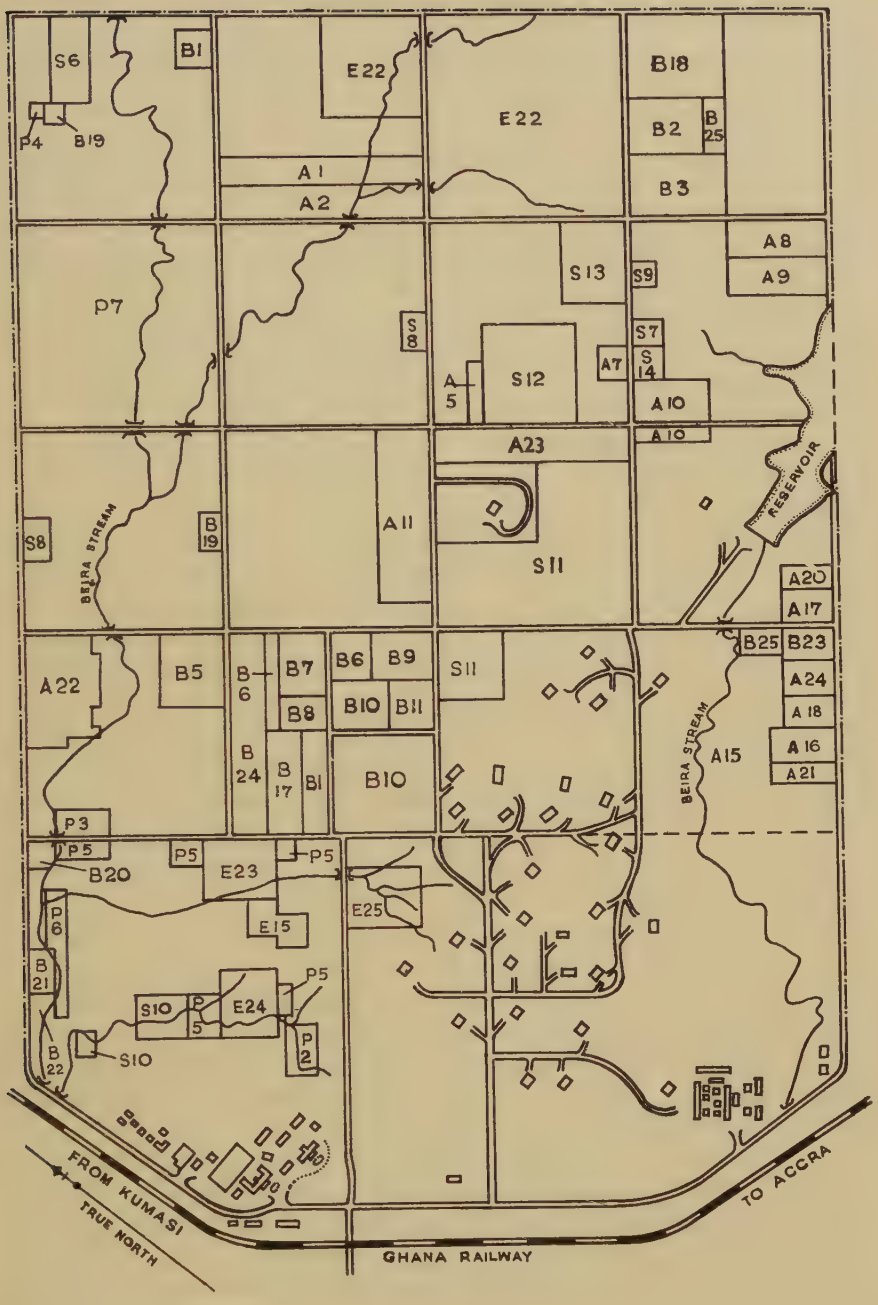
P 3–Swollen-shoot Alternative Hosts Nursery.

P 4–Collection of material showing tolerance or resistance to Swollen-shoot Disease.

P 5–Black-pod Control Trial.

P 6–Black-pod Control Trial.

P 7–Swollen-shoot Studies.


S6
B1
E22
E22
B18
B2
B25
B3
P4
B19
A1
A2
P7
S8
S13
S9
A8
A9
S7
S14
A7
A5
S12
A10
A23
A10
RESERVOIR
S8
BEIRA STREAM
B19
A11
S11
A20
A17
A22
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B1
B10
BEIRA STREAM
A15
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B20
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E25
P6
E15
B21
S10
B5
E24
P5
P2
S10
B22
FROM KUMASI
TRUE NORTH
GHANA RAILWAY
TO ACCRA

VIRUS RESEARCH

THE HOST RANGE OF CACAO VIRUSES (A. Attafuah and A. A. F. Brunt)

Laboratory tests

Sida linifolia Cav., an indigenous member of the Malvaceae, has been infected with the Kpeve virus isolate, but, as in previous tests, the plant could not be infected by the New Juaben isolate. The results of the experiment in which *Hibiscus abelmoschus* L. was found to be susceptible to New Juaben and not to Kpeve, and in which an *Hibiscus* sp. ?*manihot* was found to be susceptible to Kpeve and not to New Juaben, have been confirmed (see *Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 20). This is a further example of the differential susceptibility between these two isolates noted previously.

Experiments have continued on the persistence of a number of virus isolates in a variety of experimentally-infected host plants. This work has revealed that virus is not continuously available to mealybugs that are, from time to time, put to feed upon the infected plants. For instance, back-tests from plants of *Cola chlamydantha* and *Hildegardia barteri* infected with an isolate from Offa Igbo were positive during a period of thirty months. Subsequent back-tests were negative until the plants were coppiced, when successful virus transmissions were made to cacao by feeding mealybugs upon the new growth arising from the base of the coppiced plants. By contrast, plants of *H. barteri* infected with the Kpeve isolate continued to yield positive back-tests until the plants were coppiced, but subsequent back-tests have been negative.

The search for natural infections

Work on the geographical distribution of virus infection in *Adansonia digitata* L. has been hampered by the complete failure to establish rooted cuttings from shoots collected in the field. Observations have therefore been limited to transmissions to seedlings made with mealybugs from leafy shoots immediately after collection in the field, and to observations of virus-like symptoms on growing trees. These have been reported in previous annual reports.

A number of *Ceiba pentandra* Gaertn. felled during the clearance of land for planting, have produced new shoots with virus-like symptoms on the young leaves. No insect transmissions from these shoots have been obtained, but the results of graft transmissions are awaited. One hundred and twenty-two specimens of *Cola gigantea* var. *glabrescens* Brennan & Keay growing at Tafo have been tested, but no virus transmissible to cacao has been obtained.

The low availability of virus in such plants as they increase in size

has been noted before (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 22), and methods of obtaining vigorously-growing young shoots from mature trees, which are far too big to be climbed, are being developed.

THE INCIDENCE OF LATENT INFECTED TREES AT TAFO (J. W. Blencowe)

The results of an enquiry into the prevalence of undetected cacao swollen-shoot virus in an area of randomly planted Amelonado cacao are now accumulating.

The observations are being made in the 40-acre Block E on the Square Mile, which contained 4,000 cacao trees and saplings occupying a total of about 6 acres. The area had, for some years, been inspected every month and all trees found infected had then been removed. Since November 1957, 63 diseased trees have been found and these, together with 158 'contact' trees, were coppiced to within 6 in. of soil level. In addition 22 small and uneconomic patches of cacao, totalling 500 trees, were coppiced; these trees included 2 of the infected trees and 12 of the 'contacts'.

The shoots arising from the coppiced stumps have been inspected regularly for symptoms of virus infection. So far, symptom-bearing shoots have been produced on 48 of the infected trees, on 33 of the 158 'contact' trees, and on 66 of the 486 trees presumed to be healthy. This high level of masked infection is not surprising, for swollen-shoot virus has devastated most of the cacao in this district; it does, however, illustrate the difficulty of eradicating the disease even when inspection of the crop is frequent and highly skilled.

A further three uneconomic plots of cacao, involving 305 trees, have recently been coppiced, but only 12 of these trees have so far been found to be infected.

CLASSIFICATION OF ISOLATES (A. Attafuah)

Work on the relationships between the various isolates of viruses from cacao continues. All the results so far suggest that the isolates may be divided into two main groups. The name cacao swollen-shoot virus should be reserved for the group, which at present embodies the greater number of isolates, whose symptoms, generally speaking, include swellings of the stem or root. The virus from Kpeve, described as 'mottle leaf' by Posnette (1947), which does not produce swellings in stems or roots, is typical of a second group of isolates which may be classified together under the name cacao mottle leaf virus.

The virus from Asalu in Nigeria, whose vector is still unknown, does not fall into either of these two groups.

RESISTANCE AND TOLERANCE (J. W. Blencowe and A. Attafuah)

Amazon-type cacao is more difficult to infect with virus, using mealybugs as vectors, than is West African Amelonado. This is true whether the specimens tested are fan cuttings, seedlings, or dissected beans. For example, when 50 viruliferous mealybugs were fed on each of 250 fan cuttings taken from 50 different T17 Amazon parents, 119 of them became infected with the Kpeve virus isolate. At the same time, 19 out of 20 comparable cuttings of Amelonado were infected using similar batches of infective mealybugs.

When three viruliferous mealybugs were fed on each of 380 dissected Amelonado beans, 63 per cent. of the beans became infected with the severe New Juaben isolate, but only 43 per cent. of a similar batch of beans of the Amazon T17/1157 became infected. In a similar test with the Kpeve isolate, using six infective mealybugs per bean, 32 per cent. of the Amelonado and 26 per cent. of the T17/1157 beans became infected.

A second series of experiments with the New Juaben isolate demonstrated this difference in susceptibility to infection in another way. With batches of dissected beans of Amelonado and of T17/1853 five infective mealybugs per bean were required to infect 50 per cent. of the Amelonado, while nine mealybugs per bean were required to attain the same level of infection with the T17/1853.

Although the search for cacao immune to virus infection is continuing, the reduced susceptibility to infection of many of the Amazon varieties when compared with Amelonado could be of considerable value if it were consistent under field conditions. A programme of hand-pollinations has been started using parents chosen for their resistance to infection and the progenies will be tested.

The T17 group of Iquitos-type F1 seedling trees is, in common with many of the selections from South America, much less damaged by virus infection than is Amelonado. This tolerance could be valuable in districts where the incidence of virus infection is high, and where re-planted cacao soon becomes infected. The inherent danger of tolerant varieties is the creation of unrecognised reservoirs of infection, and it would be advisable to plant them only in carefully planned plantations, away from susceptible crops.

The lengthy series of tests of cuttings from the fifty T17 parents is still incomplete. An analysis of the results to date, based on the system of scoring for tolerance described previously (*Rep. W. Afr. Cocoa Res. Inst.*, 1955–56, p. 36), has shown that the differences between those varieties giving the 'best' score and those giving the 'worst' score are statistically significant. Within the limits imposed by incompatibility, crosses are being made between plants giving 'best' and 'worst' scores, and their progeny will be tested.

Cuttings from uninfected 'twins' of seedlings that showed a variety of symptoms when infected, have been bombarded with viruliferous mealybugs and the symptoms recorded (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 28). There is no correlation between the symptoms recorded on the seedlings and those subsequently observed when cuttings from their healthy twins were infected.

This inconsistency of response of clonal material to virus infection from a standard source is difficult to explain. Possibly symptom severity is related to the initial 'dose' of virus which the plant receives when infected. Alternatively it is possible that the standard isolate of severe New Juaben virus used in those experiments is a complex of related strains. The second is the simpler hypothesis and experiments have been started which should help to solve this problem.

BLACK-POD DISEASE

(A. L. Wharton)

EFFECT OF AGE AND SIZE OF POD ON SUSCEPTIBILITY

The title of the field experiment on which these studies are based is retained for convenience of reference to the previous Annual Report, but the scope of the investigations has been increased to provide basic information on seasonal outbreaks of black-pod disease. There is inevitably a time-lag in assessing the results of a single crop-season and the results given below are based mainly on records for the 1956 season. Of the 200 trees originally selected seven were cut out because of swollen-shoot virus infection in 1956 and a further eight in 1957.

The main results from the 1956 records are as follows:

1. Fruit setting: Setting occurred mainly at the end of February, over the period April to May, and during the months of June and July. The greatest number of fruits set in any one week were recorded in April and June.

2. Fruit-fall and physiological (cherelle) wilt: In addition to the young pods lost from cherelle wilt it has been found that an appreciable number of very young pods are shed, with the stalks attached, during the first week after setting. The external symptoms are similar to those produced by physiological wilt, and the phenomenon may be another expression of wilt on tiny fruits, but until the causes have been elucidated it seems advisable to use the separate names 'fruit-fall' and 'cherelle wilt'.

Losses from fruit-fall have been obtained by examining all labelled fruits on alternate days; the phenomenon would pass unobserved if records were taken less frequently. The periodicity of fruit-fall closely followed that of fruit setting, as given above, and physiological wilt was also most prevalent during these four periods. With the latter,

however, the number and proportion of fruits lost were more variable.

In 1956 losses from fruit-fall were comparable with those from physiological wilt. Of nearly 4,000 fruits set, 1,000 were lost from fruit-fall and 1,600 from physiological wilt. The proportion of the season's potential crop lost due to both causes (70 per cent.) corresponds to the level generally accepted for cherelle wilt losses on unselected Amelonado cacao in West Africa.

3. Potential crop: The total number of fruits borne on all the trees at any one time followed a smooth curve over the 1956 season, rising sharply from March to a maximum of 1,700 fruits at the end of June, and decreasing more gradually to December. Dividing the fruits into three age classes, *viz.* cherelles (0–13 weeks old), immature pods (13 weeks to date of ripening), and ripe pods, it was found that cherelles were most numerous at the end of June, immature pods in the middle of August and ripe pods in October.

4. Black-pod disease: Monthly records of 'black pods' are given in Table 4, for both 1956 and 1957. It may be seen that a similar distribution, with peaks in July and October, occurred in each year, although over 50 per cent. more 'black pods' were recorded in 1957 than in 1956. The Table also shows the distribution of sites of infection during each month, while Table 5 shows the division of this data between the three age classes. Where one pod had more than one centre of infection, these were recorded separately.

TABLE 4

Monthly distribution of 'black pods'

Month	*Site of Infection*							
	Proximal		*Lateral*		*Distal*		*Total*	
	1956	1957	1956	1957	1956	1957	1956	1957
April	—	—	—	—	3	—	3	—
May	2	—	—	3	5	9	7	12
June	22	5	17	42	26	67	65	114
July	35	16	26	91	23	77	84	184
August	24	19	9	43	1	7	34	69
September ..	18	30	32	48	5	9	55	87
October	24	32	65	73	5	11	94	116
November ..	10	15	36	28	2	3	48	46
December ..	—	1	10	1	1	1	11	3
Total ..	135	118	195	329	71	184	401	631

It should be noted that in 1956 all infections showing symptoms in the stalk-end depression of fruits were recorded as 'proximal', while in 1957 these infections were classified as 'lateral' unless the peduncle was seen to be diseased. In 1956 numbers of proximal infections followed roughly the same pattern as those of the spore-transmitted infections, but the more accurate records of 1957 showed that this

type of infection, due to systemic infection of the flower-cushion by *P. palmivora*, increased gradually during the season reaching a maximum in October. It seems therefore unlikely that systemic infections are an important perennial source of black-pod infection, and the two major epiphytotics recorded during the year were probably initiated by spore-transmitted infections.

TABLE 5

Age distribution of diseased pods

Age of fruits	*Site of infection*							
	Proximal		*Lateral*		*Distal*		*Total*	
	1956	1957	1956	1957	1956	1957	1956	1957
Cherelles	30	14	17	97	53	138	100	249
Immature pods ..	89	86	73	158	15	37	177	281
Ripe pods ..	13	18	103	74	8	9	124	101
Total ..	132	118	193	329	76	184	401	631

In 1957 inspection and labelling of fruits was, as far as practicable, undertaken daily and it is probable that the proximal infections recorded in this year are a true measure of the number of fruits infected from diseased cushions. If the external symptoms on these proximally infected fruits had resulted from spore infections there would have been insufficient time, between inspections, for the pathogen to grow into the peduncle and produce symptoms there. As a check, isolations are being made from cushions which bore proximally, laterally and distally infected fruits during 1957. These are not yet complete but so far *Phytophthora palmivora* has been recovered only from those which bore proximally infected pods.

Examination of Table 4 shows that the aggregate of spore-transmitted infections (lateral plus distal infections) is the main component of the two important epiphytotics during each season. Table 5 shows that the distal infections are important only during the June-July period, as they are largely confined to cherelles which decrease in number later in the year.

5. Relationship between the incidence of black-pod disease, the number of fruits present and their surface area: Thorold (*Rep. Cocoa Conf., London*, 1953, p. 108), has shown that, at any one time, there is a positive correlation between the total number of pods per tree, and the number infected by *P. palmivora*. The correlation is, however, influenced by the changing number of pods per tree as the season progresses, and a more constant association has been found between the number of infected pods and the total surface area of the fruit on the tree, calculated for the various age groups by assuming a standard shape of pod. This relationship was fairly constant through the season,

except during the 'short dry season' of August when conditions are perhaps unsuited to the spread and development of the disease from spore infections.

STRAINS OF *P. PALMIVORA* OCCURRING IN GHANA

Fifty-five isolates of *P. palmivora* have been collected from widely scattered districts covering all the cacao areas in Ghana. In preliminary tests, the isolates were first subcultured from single zoospores, and an isolate (WACRI No. G 53) collected from a diseased pod at Tafo was used as a standard for comparison. So far, those isolates examined have been very similar in appearance and in growth rates, both in artificial culture and in pods. The dimensions of sporangia collected from artificially infected pods have also been roughly similar. Some results for isolates representative of those collected in cacao area of Ashanti, Eastern and Western regions of Southern Ghana and Trans-Volta/Togoland are given in Table 6.

TABLE 6

Growth rates and dimensions of P. PALMIVORA *isolates*

Source of isolate	*WACRI Code No.*	*Mean rate of growth (cm. per day)*			*Dimensions of sporangia (μ)*		
		Oatmeal agar	*Potato dextrose agar*	*Pods*	*Mean of 200*		*Ratio*
					Length	*Width*	*L/W*
Mampong	G 7	1.7	1.1	3.3	39.1	23.5	1.66
Simpa	G22	1.9	1.5	3.9	47.7	23.8	2.00
Swedru	G31	2.3	1.6	3.7	50.2	25.8	1.95
Tafo	G53	1.9	1.5	3.8	51.9	25.7	2.02
Woropong	G49	1.9	1.3	3.6	47.5	24.4	1.95

The isolate G7 from Mampong in Ashanti is the only one so far examined which differed consistently from the others in all the characters investigated (including colony appearance on potato dextrose agar) and merits further study.

A number of isolates are to be brought from Nigeria for comparative laboratory tests with isolates from Ghana.

'DIE-BACK' OF CACAO SEEDLINGS

A block of four-week-old T82 Amazon seedlings in the Botany Division nursery at Tafo was found, in mid-December, to be severely diseased. About one-third of the seedlings were dead or diseased, although some were recovering by the development of axillary buds, and symptoms were the same as those described by Chant (*Nature, Lond.*, **180**, 1494, 1957), who found a species of *Phytophthora* responsible for a serious 'die-back' of cacao seedlings in Nigeria. The disease was extremely localised, a similar neighbouring bed of T82 seedlings

being entirely unaffected, as were two beds nearby of three-week-old Amelonado seedlings.

A *Phytophthora* sporulated freely from affected material kept in humid chambers. The fungus was readily isolated into oatmeal agar from pieces of infected stem previously surfaced-sterilised in mercuric chloride. This was contrary to the experience of Chant, who could only isolate the *Phytophthora* in Nigeria by first washing pieces of diseased material under running tap-water for twelve hours and then transferring them into sterile wounds cut in the surface of cacao pods. Chant's method was equally successful at Tafo, although the washed tissue always yielded the *Phytophthora* when plated directly, without making an intermediate culture on pods. It remains to be seen if these *Phytophthora* isolates can reproduce the symptoms when inoculated on to healthy seedlings.

P. PALMIVORA ON CACAO IN THE BRITISH CAMEROONS

Mr Wharton visited the British Cameroons to investigate a report that *P. palmivora* might be associated with 'Leafless Twig' disease of cacao. No pathogens were isolated from the 'leafless twigs' themselves, from seedlings, or from chupons showing 'paint-brush' symptoms before jorquetting. A fuller investigation into the disorder is reported on p. 73.

A tip necrosis of flush leaves common on the mature cacao at Tombel in the Cameroons does not appear to be due to a nutrient deficiency, as reported by previous investigators. The wet rot of the tip of the leaves advances most rapidly along the main and secondary veins, and the area of tissue in advance of the wet rot is often translucent and colourless. A species of *Colletotrichum* was invariably isolated from the necrotic areas; *P. palmivora* was also seen and collected from the surface of affected tissue but was never present alone. This is the first record for West Africa of *P. palmivora* occurring naturally on leaves of mature cacao.

Symptoms of the disorder were produced on healthy flush leaves by spraying them with a mixed suspension of *Colletotrichum* and *Phytophthora* spores but limited time and equipment precluded further experiments. From these observations it can only be suggested that this necrosis is caused by one or both of these pathogens.

POD INOCULATION TECHNIQUES

A standard technique for inoculating cacao pods with *P. palmivora* is being developed. A satisfactory method would be useful for testing cacao selections for resistance or tolerance to black-pod disease, and also possibly for screening fungicides in the laboratory. The number of fruits available would in many cases be small, especially when

experimenting with new cacao selections during the early years of bearing, and the object, therefore, has been to produce multiple, but readily countable, infections on individual cacao pods.

Successful mechanical inoculations of detached pods were made with spore suspensions of *P. palmivora* mixed with various abrasive dusts. It soon became apparent, however, that infections could occur without injury of the pod cuticle, provided the conditions permitted satisfactory spore germination. Indirect germination of spores seemed to be best if the media were well aerated. Temperature did not appear to be critical; sporangia produced zoospores freely at ambient temperatures often as high as 84°F., and nearly all these zoospores germinated. Mixed suspensions of sporangia-producing active zoospores can cause multiple infections on undamaged pods.

Spore suspensions were inoculated using soaked filter-paper discs, or sprays, or by partially immersing the pods in the suspension. When pods had been immersed in spore suspensions, many hundreds of discrete lesions were visible after twenty-four hours. A few of these quickly enlarged and coalesced, but the great majority of them failed to develop any further, possibly because of a hypersensitive reaction by the host tissue.

If the ungerminated sporangia in the mixed suspensions could be separated from the liberated zoospores, then it would be possible to ensure that experimental infections are all initiated within a limited period of time, for the zoospores all germinate in forty-five to sixty minutes. This would be valuable because lesions, once initiated, would rapidly obscure others which started developing later. Preliminary attempts to filter off the ungerminated sporangia from the liberated zoospores have been only partially successful, but this work is continuing.

RESISTANCE AND TOLERANCE

Observations have been made on the incidence of black-pod disease on trees in the WACRI 1st Clonal Trial. Infected pods have become extremely numerous because diseased pods have been left on the trees to act as sources of infection. This system has not resulted in an even distribution of infection, but nevertheless certain clones have shown consistent differences. For instance, clone A12 had an average of twelve 'black pods' per tree over the whole year, while ACU85, a clone which yields as well as A12 when harvested normally, had an average of only three 'black pods' per tree. The results of this work are still incomplete. Similar observations are being made on the 9th Progeny Trial Area, although here normal harvesting procedure must be adhered to and the incidence of black-pod disease is thus necessarily lower.

MEALYBUG STUDIES

(P. F. Entwistle)

JOINT WACRI-DEPARTMENT OF AGRICULTURE MEALYBUG CONTROL TRIALS

A new attempt to control the vector insects of swollen-shoot disease of cacao in Ghana by destroying the attendant ants is being made. A series of trials, conducted in conjunction with the Department of Agriculture, were begun in November 1956 (see *Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 37), based on information obtained from earlier pilot experiments when a comparison of the formicidal properties of several insecticides indicated that dieldrin gave good ant control.

Pseudococcus njalensis, the principal vector of swollen-shoot disease in Ghana, constitutes 98 per cent. of the total numbers of mealybugs on cacao and is almost entirely dependent for its survival upon the attentions of crematogasterine ants. If these ants are destroyed the accumulated honey-dew secretions of the adult mealybug swiftly become infected with fungi and bacteria and the mealybugs themselves die; it is not known whether death is due to the tissues becoming infected or the respiratory system occluded. Normally most of the adults of *P. njalensis* live in tents made by ants. These tents deteriorate when the ants are killed and the mealybugs move from them. An increase in parastitism further decimates the mealybug populations, and predators probably also play a part, though their effects are not as easily measured.

Dieldrin was applied by motorised mistblowers, at the rate of 1 lb. of toxicant in 22 gallons of water to each acre. Four operators walked from a base line along parallel lines 4 yards apart, spraying the trunks of both cacao and forest trees, with particular attention to the latter, to a height of about 8 feet. At the end of each sector, the operators turned and retraced their path treating the opposite sides of the trees. One additional man followed behind the main gang applying dieldrin, at the same concentration, to the cacao canopy, 2 gallons being dispersed in this way in each acre.

Mealybugs other than *P. njalensis*, which amount to only 2 per cent. of the total mealybug population, include about ten different species, none of which is as closely associated with ants as *P. njalensis*. To attempt control of this fraction of the population, and any *P. njalensis* surviving the dieldrin, malathion (which has proved effective against mealybugs on other crops) was applied to some of the plots as a canopy spray at the rate of 4 oz. of toxicant in 20 gallons of water per acre.

The experiments are summarised in Table 7.

TABLE 7

Experiments on mealybug control

Site of trial	*Area of treated units (acres)*	*Treatments*		
		First dieldrin application	*Second dieldrin application*	*Malathion application*
Oyoko	200	3/12/56 to 3/1/57	20/3/57 to 25/4/57	None
WACRI Square Mile	40	6/2/57 to 15/2/57	None	31/7/57 to 2/8/57 (on 50% of plots)
Discrete outbreaks	2–4	17/12/56 to 31/12/56	11/2/57 to 20/2/57	4/4/57 to 8/4/57 (on 50% of plots)

Ant estimations

Ants were counted on labelled trees along transects through the plots, and for easy recording ant-activity was classified into three groups:

A. Individual ants
B. Columns of ants
C. Active nests

The ants were identified in the field, mostly to genera, but with the principal mealybug-attending ants, to species. Separate records were kept for ants found on cacao and on forest trees.

Mealybug estimations

In the Oyoko trial and the discrete outbreaks, which were in farmer's cacao, it was not generally possible to make counts of mealybugs on complete felled trees. Instead, counts were made to hand-height on randomly selected trees, and as the cacao was very mixed this included everything from seedlings to mature trees. This method is open to criticism, but its feasibility as a means of identifying gross population fluctuations was well illustrated at the Oyoko trial where counts were made on complete trees (felled as virus contacts) in half of the treated area. Data obtained from these followed very closely that from hand-height counts, although naturally at a higher numerical level.

In the trial in WACRI Square Mile vector population estimates were made entirely on complete trees felled for that purpose. Here, very detailed records were taken as twigs were examined under the microscope and accurate counts of nymphal stages made. In the other two trials examination for vectors was made with a hand lens, and whilst it was simple to estimate adults in this way it was impossible to count nymphs which were thus recorded merely as present or absent. Consequently, for a basis of comparison in the data presented below, infestation refers only to the presence of adult

mealybugs. Conveniently, it is precisely this stage of the life cycle which is most susceptible to control factors operating in the absence of attendant ants, i.e. infection of honey-dew secretions and attack by hymenopterous parasites.

Results

Oyoko. A fortnight after the first dieldrin application organised ant activity had broken down but ant populations increased relatively rapidly up to the time of the second treatment, after which recovery was slow. Pre-treatment levels of population were not re-established till over a year after the date of the second application. The numbers of active ant nests recorded are shown in Figure 1, and it may be seen that they fell to a minimum about two months after the second application.

Figure 2 shows the percentage changes in numbers of adult mealybugs in the control and treated areas. Two dieldrin applications have been sufficient to effect a minimum reduction of 90 per cent. for a period of twelve months. In the treated area counts of *P. njalensis* actually remained for some time at zero, the only vectors found being minor species less dependent for their survival upon the presence of ants. Whilst with control exerted largely against *P. njalensis* there was a change in the proportions of different mealybug species in the vector complex, actual numbers of minor species varied relatively little during the year.

To date, about eighteen months after treatment, this diminution in vector populations has had no apparent reflection in the incidence of swollen-shoot disease in the area. Since the maximum latency period of these viruses may be up to two years, counts of visibly-infected trees must continue for at least one more year before any conclusions may be drawn as to the success of this new attempt at the control of swollen-shoot disease. To maintain mealybug control further spraying is being contemplated.

It must be emphasised that even if some control of the disease becomes evident this method needs considerable development before it can be recommended for practical purposes. Not only is it expensive but the widespread application of heavy doses of insecticide in the present manner may have side effects which cannot now be foreseen.

WACRI Square Mile. This trial illustrates the inadequacy of one application of dieldrin in a relatively small area in effecting an acceptable reduction in vector populations through ant control. There was a good degree of ant control of short duration (Fig. 1), but populations soon increased and were sufficiently organised to permit the relatively early re-establishment of the mealybug population.

At the eighth fortnight after the first dieldrin application populations of adult mealybugs had fallen to 3.0 per cent. of their initial pre-treatment count (Fig. 2) and less than twelve months after spraying had exceeded control plot figures.

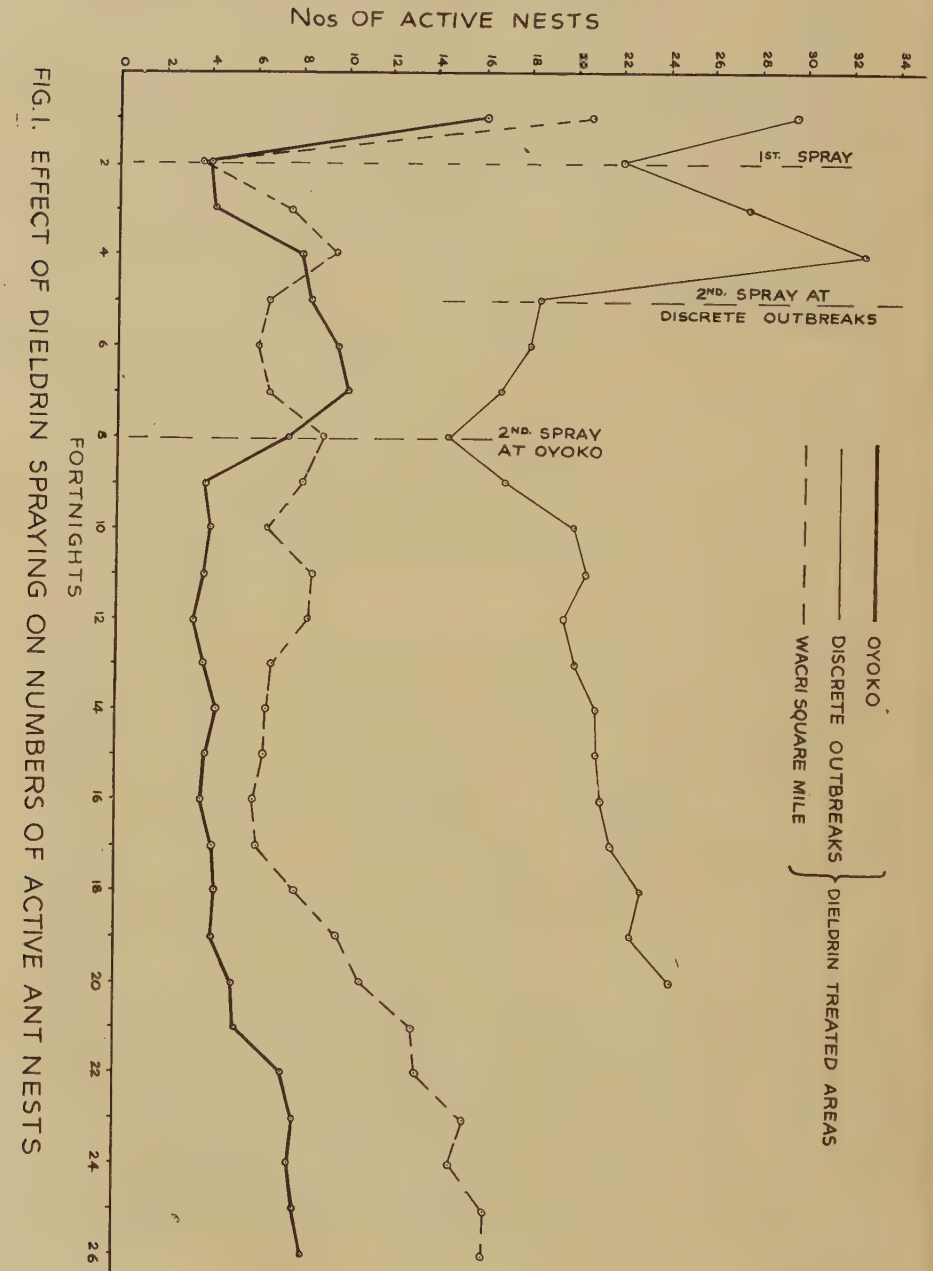


FIG. I. EFFECT OF DIELDRIN SPRAYING ON NUMBERS OF ACTIVE ANT NESTS

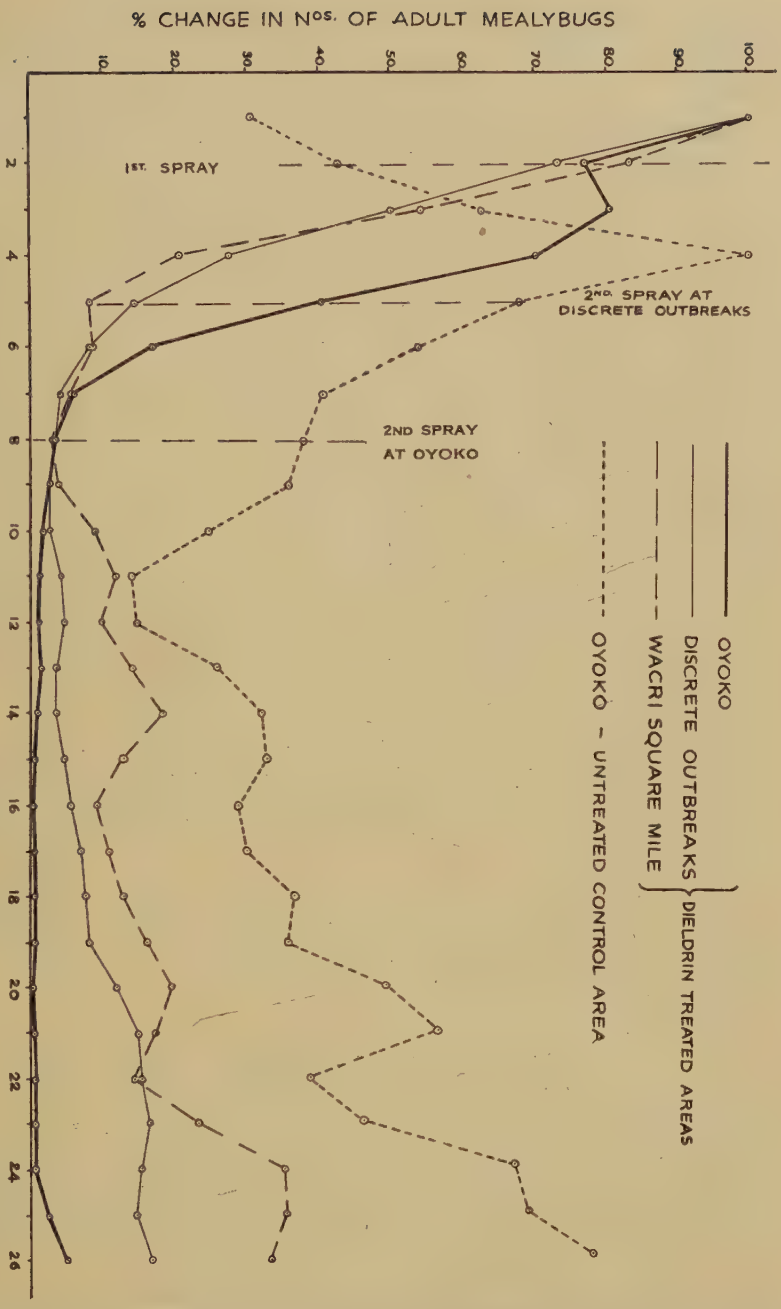


FIG. 2. PERCENTAGE CHANGES IN THE NUMBERS OF ADULT MEALYBUGS (ALL SPECIES) FOLLOWING ANT CONTROL WITH DIELDRIN

Changes in the numbers of trees infested followed a similar pattern to population fluctuations. Prior to spraying 75 per cent. of trees in the treated area had mealybugs, the figure falling to 20 per cent. in

the eighth fortnight after dieldrin treatment but by the twelfth fortnight rising again to pre-treatment levels and subsequently above these.

Malathion, which was applied to half of the treated area plots, had no detectable effect on mealybug populations.

Discrete Outbreaks. These trials were ended on the 3rd of January 1958 having run for twelve months from the date of the first dieldrin application. Of the seventy-six outbreaks selected by the Department of Agriculture for the trial, eight were visited every fortnight by ant and mealybug estimating teams from this Institute. At its best ant control was not good (Fig. 1) populations having returned quite close to pre-treatment levels within five months of the initial dieldrin application. This is probably due to the small size of the sprayed areas, which were more likely to be reinfested from outside than were the two larger trials.

Vector control at below the 90 per cent. level persisted only for seven months and in the last three months of the experiment a definite rise was apparent (Fig. 2). By the eighth fortnight after the first dieldrin application populations had fallen to 2.5 per cent. of pre-treatment levels and from then on there was a steady recovery until, by the close of the experiment in the twenty-fifth fortnight, they had risen to 16.6 per cent. of their initial level.

Changes in numbers of trees infested (from counts of mealybugs to hand-height on the trees) followed a similar pattern, falling from an initial level of 26.2 per cent. to 5.2 per cent. at the ninth fortnight after the first treatment and rising to 12.3 per cent. at the conclusion of the experiment.

Estimates of virus incidence did not demonstrate any control of swollen-shoot disease. This was to be expected in view of the long latent period before symptom expression.

CAPSID STUDIES

(C. G. Johnson and P. F. Entwistle)

JOINT WACRI-DEPARTMENT OF AGRICULTURE CAPSID CONTROL TRIALS

Preliminary trials were carried out in 1956 to compare the effectiveness of mistblown aqueous emulsions of endrin, aldrin, dieldrin, *gamma*-BHC and heptachlor (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 41). No significant differences in performance were detected between aldrin, dieldrin and *gamma*-BHC, all of which gave good control. On the endrin plots, however, capsid damage continued at an extraordinary low level, while insufficient control was obtained

with heptachlor. Following these results endrin, dieldrin and aldrin were selected for a large-scale trial in 1957, the former for its apparently outstanding performance, and the latter for its relative cheapness. In this trial three plots, each of about 100 acres, were used. In addition small plots of 3–4 acres each were used for the comparison of aldrin, *gamma*-BHC and malathion.

In these trials the experimental procedure was made more rigorous. Untreated controls were included for comparison with treated plots, and allowances were made for the variation in tree density between different plots. In some plots there may be three times as many trees per acre as in others, and if mere numbers of damaged trees per acre, after spraying, are used to measure treatment effects, comparisons between different insecticides could be suspect. In addition pre- and post-treatment assessments of the amount of canopy have been made so as to estimate regeneration after treatment.

In all plots the insecticides were initially applied twice at 4 oz. toxicant in 5 gallons of water per acre, with a one-month interval, using a 'Motoblo' mist-sprayer. Subsequently the large-scale units were resprayed, again twice with a one-month interval, six months later, using 1 oz. toxicant in 5 gallons per acre in each operation. The dieldrin units did not come up to expectation, and these plots were therefore resprayed with *gamma*-BHC (2×1 oz. applications) instead of dieldrin. The small-scale units were also resprayed twice at one month interval at about the same time (2×4 oz. toxicant per acre). The malathion plots did not show effective control, and they were re-allocated to the other treatments.

Small-scale units

In the small-scale units 56 days after the initial treatment 29 foliage-damaged trees were found in the BHC plots, out of a total of 6,854 trees, while in the aldrin plots out of a total of 8,714 trees 106 had damaged foliage and pod damage was noted on 30 trees. Of 9,955 trees treated with malathion 260 had foliage damaged as well as 708 with damage on pods. This was considered more than could be tolerated after spraying, and this insecticide was therefore abandoned.

At the third re-survey 56 days after the second treatment *gamma*-BHC, with 79 trees damaged in 9,098, showed a greater degree of control than was seen on the aldrin plots, where 168 trees were damaged in 11,277. Damage in the controls was heavy.

Large-scale units

Two months after the first treatment damage in the endrin and aldrin plots was tolerable, with the difference in favour of the former.

In the dieldrin plots initial damage was much higher, and this treatment was abandoned.

After the second treatment, re-surveys up to the fifty-sixth day showed only 19 newly foliage-damaged trees out of a total of 4,408 trees on the endrin plots whilst 58 trees out of 4,855 on the BHC plots had foliage damage and 2 trees had pod damage. The aldrin unit had 446 newly damaged trees scattered throughout the plot out of a total of 6,666, and was particularly heavily affected along the perimeter.

This work will continue for one more year and full numerical data will be published later.

POD HUSK MINER

MARMARA INCIDENCE (C. G. Johnson and P. F. Entwistle)

With the appearance of the main cocoa crop the small moth (*Marmara* sp, Lepidoptera, Gracillariidae), which causes the well-known 'scribbling' on pods, became extremely common at WACRI. Infestation is always beneath the epidermis of succulent tissue such as green pods or fans and chupons where hardening has not yet occurred. As the larva matures the initial straggling mine develops into a blotch causing peeling of large pieces of epidermis. Ripe pods and hardened flush tissue are never affected, though they commonly show traces of earlier attack. This damage is without effect either on quality or quantity of beans; but sometimes it is difficult to tell if damaged pods are ripe, and in any case it is unsightly and possibly disturbing to farmers. Attack to fans and chupons often goes unnoticed.

A survey of sprayed and unsprayed cacao indicated an association between spraying and increase in the incidence of miner, and enough data are now available to demonstrate this quantitatively. The bulk of information was on infestation of pods collected during the main crop season; but subsequently a survey was made of *Marmara* incidence on fans.

At the Oyoko experiments on the control of ants and mealybugs, tree trunks were heavily sprayed with dieldrin—two applications with a two month interval between, each application at 1 lb. of toxicant per acre—while no dieldrin was sprayed on the control plots. In addition both areas were treated twice with *gamma*-BHC. As indicated in Table 8 *Marmara* attack was very high in the dieldrin-treated area, and very low in the control area. One hundred pods were sampled from each of several farms in the two areas, and the results can therefore be read directly as percentages. The degree of

damage to the pod is expressed as the percentage of surface damaged by the miner.

TABLE 8

Number of pods damaged by MARMARA *at Oyoko*

Plot No.	*Degree of damage (% pod surface covered by miner)* 0	1–30	30–60	60–100
Unsprayed Plots				
5a	77	22	0	1
5b	65	34	1	0
5c	55	44	1	0
5d	49	48	3	0
5e	54	45	1	0
5f	69	31	0	0
Sprayed Plots				
2	0	5	13	82
3a	0	3	10	87
3b	0	3	7	90
3c	0	1	11	88
3d	0	11	15	74
1a	0	15	34	51
1b	0	9	13	78
4a	0	10	16	74
4b	0	15	26	59

In this example the control and treated areas were 1 mile apart. It could be argued that the difference was due to locality rather than to treatment: later surveys of other areas however did not support this view and Table 9 shows the results of a further survey on the WACRI Square Mile, where sprayed and unsprayed areas are close together and indiscriminately situated with respect to each other.

TABLE 9

MARMARA *damage at WACRI*

	Degree of damage (% pod surface covered by miner) 0	1–30	30–60	60–100
Unsprayed plots				
Number of pods	436	849	451	649
Percentage of total	18.3	35.6	18.9	27.2
		53.9		46.1
Sprayed plots				
Number of pods	139	839	644	978
Percentage of total	5.3	32.2	24.8	37.8
		37.5		62.4

The difference in incidence though in the same direction, i.e. more on sprayed plots, is not so striking as at Oyoko. This is probably because so much of WACRI is sprayed that the unsprayed areas where the miner was unexpectedly prevalent are close to sprayed

ones and so were also affected. However, as shown in Table 10, the incidence on unsprayed plots was associated with the distance to the nearest sprayed area, and it thus appears that a sprayed area can affect an unsprayed one. Up to 300 ft. the effect is strong but beyond this it begins to disappear.

TABLE 10

Percentage distribution of degree of MARMARA *damage in relation to distance from nearest sprayed plot (selected data)*

Distance to nearest sprayed plot (ft.)	*Degree of damage (% pod surface covered by miner)*			
	0	1–30	30–60	60–100
1,980	65	35	0	0
1,320	81	19	0	0
620	42	41	13	4
390	8	76	15	1
350	48	49	3	0
320	60	37	3	0
210	3	11	33	55
165	12	61	24	3
150	0	38	47	15
20	1	13	28	58
20	2	4	17	77
9	2	18	26	54
5	0	18	22	60

Note: 100 pods taken at each position

When WACRI Square Mile was surveyed for *Marmara* incidence on fan tissue, dieldrin spraying had been in abeyance for six months and in addition all plots (i.e. untreated and also those previously dieldrin-treated) had received two applications of *gamma*-BHC. The effect was to give results which were not so clear cut, though a diminishing degree of infestation with distance from an area previously treated with dieldrin, was still detectable.

The cessation of dieldrin spraying has probably allowed parasite populations preying on *Marmara* to increase, and a comparable degree of miner damage was found in plots previously treated with dieldrin and in untreated plots. The application of *gamma*-BHC to all plots probably tended to equalise the effects of the more normal parasite distribution so inducing a similar intensity of *Marmara* attack in the two treatments.

The rise in *Marmara* illustrates in a classical way how the application of a powerful insecticide, while having desirable effects in one way, may inadvertently produce undesirable side effects. In any community, animals and plants live by and on each other so that their population levels attain a quasi-stable state. If one of the regulating factors (say a potent parasite) is eliminated or reduced, a

violent population surge of a hitherto unnoticed organism may occur: and, like *Marmara*, it may become of practical importance and therefore perhaps more noticeable. With *Marmara* the dangers are twofold: that resulting from the effects of an increased *Marmara* population on husbandry; and the danger that, though the yield is not affected, the appearance of the pods may turn farmers from the otherwise beneficial effects of capsid control—effects which generally outweigh the small nuisance of increased *Marmara*.

It is too early yet to say if the rise in *Marmara* is due to a specific chemical, or merely to an excessive dosage of any of the chemical sprays now being used; the experience at Oyoko, where both control and treated areas received two applications of *gamma*-BHC, seems to incriminate the more persistent chlorinated hydrocarbon dieldrin, though it should be remembered that the dieldrin dosage was much higher than that of *gamma*-BHC, and the effect may be due to dosage rather than to the particular insecticide.

AN EXPERIMENT IN *MARMARA* CONTROL (P. F. Entwistle)

Though it may be possible and if so certainly cheapest and safest to control *Marmara* by reducing the frequency or dosage of capsid spray, an attempt was made at its direct control by insecticide. The insecticide selected was a semi-systemic, diethyl paranitrophenyl thiophosphate (Bayer, Folidol E-605), which was applied, by means of a pressure retaining knapsack-type sprayer, as an aqueous emulsion. Starting from the manufacturer's suggestion that a concentration of 0.06 per cent. should be employed against borers (e.g. Codling Moth larvae) a small pilot test was made.

Using three different concentrations of Folidol on three groups of ten infested pods and ten infested chupons (average infestation rate approximately three insects per pod or chupon), with equal numbers as untreated controls, estimates of larval mortality were made two days after spraying. The results are presented in Table 11.

TABLE 11

Percentage control of* MARMARA *sp.*

	Concentration of Folidol		
Tissue treated	0.06%	0.02%	0.01%
Pods	85.0	97.4	87.8
Chupons ..	82.6	95.6	100.0

* Calculated by Abbotts' formula: $\frac{c-t}{c} \times 100$,

where c = % alive in control
and t = % alive in treatment.

The figures in the body of the table represent percentage control

as calculated by Abbotts' formula, which takes into account mortality in the control treatments. Due to the small samples taken the results naturally show some inconsistencies, but it was apparent that using Folidol at a concentration of 0.01 per cent. good control could be obtained.

Hence in a second series of pilot trials 0.01 per cent. was selected as the maximum concentration whilst two lower ones, 0.005 and 0.0025 per cent., were also included. Due to the absence of suitably infested pods the second series was tested entirely on chupon tissue. Percentage control was estimated at 1, 2, 3, 4, 5, and 6 days after treatment using 100 chupons (average infestation rate approximately 125 insects per 100 chupons) for each day/concentration and a similar number for untreated controls. Table 12 shows the mortalities obtained.

TABLE 12

Percentage mortality of MARMARA *sp.*

% *concentration*	*Days after spraying*					
Folidol E-605	1	2	3	4	5	6
0.01	79.7	98.9	97.5	98.3	98.0	98.8
0.005	73.4	85.8	87.1	81.8	88.7	93.8
0.0025	47.8	62.7	71.9	80.2	77.2	83.0

Slight incongruities in the Table are probably due to variable numbers of larvae in the process of moulting at the time of treatment; during moulting larvae do not feed, and it is possible that when the process is complete the insecticide will have decayed to a non-lethal level. This contention has supporting evidence from the manufacturers who state that the residual life of Folidol E-605 within plant tissues is of the order of two to three days.

The figures in Table 12, when graphed, give asymptotic curves indicating that the fullest possible degree of control has been obtained by the sixth day. It appears that, provided there is adequate coverage, a concentration of 0.01 per cent. gives an acceptable degree of control, though this has yet to be confirmed in larger scale experiments on both pods and chupons.

POLLINATION STUDIES

(Helen M. Entwistle and Joyce Hurd)

THE EFFECTS OF INSECTICIDES ON POLLINATION, FLOWER SETTING AND NUMBERS OF POLLINATOR INSECTS

On the 30th of April 1957 an experiment was started to study the

effects of spraying on insect pollinator populations and on setting and flower fall. The experiment occupied three 5-acre blocks of cacao, one of which was sprayed monthly with *gamma*-BHC, one with dieldrin and the third kept untreated as a control area. The initial insecticidal treatment was made at 4 oz. of toxicant applied as an ordinary capsid spray in 5 gallons of water per acre; thereafter treatment was at the rate of 1 oz. per acre.

At the beginning of the experiment, the three areas were in a region of cacao receiving routine dieldrin treatment for capsid control, and the *gamma*-BHC and control plots were therefore insulated by a perimeter strip of untreated quarter-acre plots.

Insect density

Insect counts in flowers made daily at 6.30–7.30 a.m., 10.30–11.30 a.m. and 1.30–2.30 p.m. revealed a misture of small Diptera (principally Cecidomyidae and Drosophilidae), Hymenoptera (ants and small Parasitica), Aphididae and Collembola. Actual pollinating insects (Ceratopogonidae) formed a very small proportion of this complex and in the first forty-eight weeks of the experiment only 191 individuals were found. The distribution of these between the three treatments is shown in Table 13.

TABLE 13

Numbers of Ceratopogonidae in sprayed and unsprayed plots

Period after spraying	*Treatment*		
	Dieldrin	*gamma-BHC*	*Control*
First 24 weeks ..	21	19	57
Second 24 weeks ..	20	34	40
Total 48 weeks ..	41	53	97

Due to the small numbers of actual pollinators, it is not possible to comment on seasonal trends nor on a differential effect of spraying on these. With most of the insects found in flowers there was little apparent difference in population densities (expressed as numbers of insects per hundred flowers) between the two insecticidal treatments; but sprayed plots tended to have a lower density of insects than the controls. The same general seasonal trends were followed in each of the three plots.

Flower density

There was no apparent difference in flower densities between the three areas (measured weekly on ten trees at random in each quarter-acre plot, up to 6½ ft. on the trunk). Fluctuations in flower density

followed a normal pattern, falling from the beginning of the experiment to nil in June 1957, and not beginning to increase again until December, when a steady rise brought numbers back to the initial level by the forty-eighth week.

Pollination rates

Pollination rates have followed flower densities quite closely and there has been no detectable difference in pollination rates associated with the different Ceratopogonid density on the treated and the untreated areas (see Table 13).

In estimating pollination rates five trees were selected in the centre of each 5-acre block. All open flowers were stripped from the trees every Sunday, and during the remainder of the week freshly-opened flowers were marked daily and examined for pollination on the following day. Each tree was divided into 'trunk' and 'canopy' by a red line 10 ft. above ground level and separate counts were made above and below the line; flowers falling to the ground were also counted.

Setting rates

Setting did not appear to be affected by the heavy applications of insecticides made in the experiment, fluctuations in numbers of sets following closely the pattern described for flower density and for pollination rates.

Counts were made of the number of sets each week on those trees used in flower density estimates, only sets below a height of 6½ ft. being recorded. The counts were restricted to sets of 1 cm. long or less.

MINOR PESTS OF CACAO

(P. F. Entwistle)

SCOLYTIDAE

Following a report from the Director of Agriculture for Sierra Leone that boring beetles were preventing the establishment of cacao seedlings there, insects and specimens of damaged tissue were obtained. The damage symptoms reported, and those seen in the infested chupons sent to this Institute, are similar in nature to those described in previous reports from the Ivory Coast. There infestation is considered to be a dry season phenomenon, though none-the-less of a fairly serious nature.

The West African Timber Borer Research Unit in Kumasi tentatively identified the beetles from Sierra Leone as *Xyleborus morstatti* Hag., whilst an entomologist in Sierra Leone considered that they

might be *X. compactus* Eich., known there as a pest of coffee. As there appears to be some confusion specimens have been sent to the Commonwealth Institute of Entomology for correct identification.

The above reports stimulated interest in this family of beetles at Tafo and in a space of two weeks ten different species (eight of them ambrosia beetles) were recovered from dead and dying cacao tissues. Of particular interest was the attack by Scolytidae observed in a group of about fifteen mature trees dying from unknown causes. Attack began in the very early stages of the appearance of mortality symptoms and was concentrated at litter level but extended to over 10 ft. up the trunk and to more than 15 in. below soil level. The species (tentatively identified by WATBRU) recovered from the wood of these trees included *Xyleborus semigranosus* Blandf., *X. cameroonus* Hag., *X.* (*premnobi* group) *xylocranela* Sch., *X. mascarensis* Eich., and two unidentified species of *Xyleborus*.

That *Xyleborus* attack was not the cause of death was indicated by the fact that not all the trees which died had scolytid damage. Cotterell (*Department of Agriculture Year Book*, 1927 and 1929) recorded apparently similar examples of this type of scolytid attack from several areas in West Africa. The true cause of death of the trees is as yet unknown, as it was at the time of Cotterell's publications when it was enigmatically defined as 'morte subite'.

At Tafo, Scolytidae are frequently encountered in cacao tissue that has been previously damaged by some primary pest (e.g. capsids or the Cerambycid beetle *Tragocephala gorilla* Thomp.). This is usually terminal fan or chupon tissue and Scolytidae of the biological group known as bark beetles (as opposed to ambrosia beetles) are predominant. These are largely *Hypothenemus* sp. (probably *pusillus* Egg.) though two species of *Xyleborus* (one probably *X. sharpae* Hop., the other unidentified) have been noted.

CERAMBYCIDAE

Tragocephala gorilla Thomp. has frequently been recorded from cacao in West Africa, particularly in areas east of the Belgian Congo (where it would seem to be replaced by other species of the same genus). Previous observations on its biology are incomplete in that the unique behaviour of the larva has been overlooked.

Attack is principally on chupon tissue but also occasionally on fans. Before laying the egg the adult female beetle first ring-barks the stem somewhere between 2 in. and 10 in. below the apical bud. The egg is then deposited in a slit about $\frac{1}{2}$ in. above the ring-barking and is wholly embedded in the tissues. Naturally, the stem above dies in a very short time. Upon eclosion the young larva burrows upwards into this dead or dying tissue, often to the base of the apical bud.

Holes for the ejection of frass and excess wood are made at irregular intervals. Subsequently the larva turns round and proceeds to eat the living wood below the point of ring-bark. In seedlings which have not jorquetted this causes death, or severe damage, whilst in those which have produced fan branches the larva normally passes below the jorquette with the result that all tissue above dies. Damage may extend up to 24 in. below the site of oviposition.

It is interesting that larvae removed from the dead wood, above the ring-barked region, will not accept an artificial burrow made in living wood, but will either die or escape; larvae which have already invaded the living wood readily accept it again. The reasons for this curious behaviour are obscure; but it could be due to different nutritional requirements of the early instar larvae or to an initial negative geotropism. It has been observed frequently that the upward movement of the young larva is interrupted by the presence of *Hypothenemus* sp. (Coleoptera, Scolytidae) in the dead terminal tissue. Whether the development of larvae affected in this way proceeds normally is not known.

LEPIDOPTERA

During the past year routine breeding of lepidopterous larvae collected from cacao in the field has been undertaken, and recently more than twenty species of moths were sent to the Commonwealth Institute of Entomology for identification.

Eulophonotus myrmeleon Feld., a well-known Megalopygid wood borer recorded from the Belgian Congo to the Ivory Coast, was noted for the first time (at Oyoko) attacking the tap-root of a young bearing tree. There were two entrance holes into the root, one at 4 in. and the other at 12 in. below soil level, the lower burrow containing two larval parasites and the upper burrow one healthy larva of *E. myrmeleon*. This species has also been noted several times at Tafo attacking the main trunk of mature trees, which, as far as is known, is its normal habit.

ESTABLISHMENT AND MAINTENANCE TRIALS

(R. J. Benstead and R. W. Smith)

EXPERIMENTAL PLOTS

The yields from the experimental plots have increased considerably, despite heavy cherelle wilt and fruit drop following a long spell of rain during the early part of the season.

In the Amelonado Spacing Trial, planted ten years ago, $7\frac{1}{2} \times 7\frac{1}{2}$ ft.

spacing has again given the highest yield per acre. Data for the 1956–57 and 1957–58 seasons are included in Table 14.

TABLE 14

Yields from the Amelonado Spacing Trial for the 1956–57 and 1957–58 crops

Spacing	15′×15′	12′×12′	10′×10′	7½′×7½′	7½′×6′	6′×6′	5′×5′	4′×4′
Equivalent density (trees per acre)	193	302	435	774	968	1,210	1,742	2,722
Pods per tree								
1956–57	25.1	15.8	13.2	11.6	7.5	5.6	4.8	2.4
1957–58	47.0	38.7	31.0	19.4	14.2	9.4	7.6	4.1
Dry cocoa per acre								
1956–57	440.8	433.2	522.4	815.5	657.4	612.7	757.0	601.3
1957–58	755.9	974.0	1,123.8	1,251.3	1,145.5	947.8	1,103.3	930.0

Data from the Upper-Amazon Spacing and Pruning Trial are given in Table 15.

TABLE 15

Yields from the Upper-Amazon Spacing and Pruning Trial for the 1956–57 and 1957–58 crops

Spacing	8′×8′		10′×10′		12′×12′	
	1956–57	1957–58	1956–57	1957–58	1956–57	1957–58
Unpruned plots						
Pods per tree	5.69	10.42	8.74	19.22	10.42	28.01
Dry cocoa per acre (lb.)	322.4	590.5	317.6	696.7	262.2	704.9
Pruned plots						
Pods per tree	5.16	10.64	9.19	18.68	12.34	27.07
Dry cocoa per acre (lb.)	292.4	602.9	333.9	677.2	310.6	681.3

There is no difference in yield between pruned and unpruned trees in this trial. On the 2nd Establishment Trial pruned Amelonado cacao has yielded slightly less than unpruned cacao, while on the Amelonado Pruning Trial, now in its second year from bearing, pruned trees have yielded more than twice as much as unpruned trees. The Amelonado Pruning Trial consists of 2 acres of cacao, planted at 8×8 ft. spacing. Half the plots are pruned, that is all chupons are removed and the trees restricted to one jorquette. It is proposed to apply a fertiliser dressing to half of the pruned and unpruned plots in June 1958.

PLANT BREEDING AND SELECTION

(D. R. Glendinning)

PROGENY AND INTRODUCTIONS TRIALS AT TAFO

The Trinidad Introductions, planted thirteen years ago, have shown a considerable overall increase in yield, probably due largely to shade reduction and partly to the application of 1 cwt. of triple super-phosphate per acre early in the year. Most of the approved types have given the equivalent of 1,000–1,500 lb. dry cocoa per acre, the highest yielder being selection T12 which, despite a low wet todry cocoa conversion ratio (see below), has given over 1,900 lb. per acre. The performance of T12 and three other approved types are included in Table 16.

TABLE 16

Performances of some selections: 1957–58

	Age from planting out (years)	*Estimated dry cocoa per acre (lb.)*
Introductions		
Trinidad Introductions Area 14′×14′		
T12	13	1,920*
T76	13	1,595*
T56	13	1,465
T16	13	1,460
T11	13	1,415*
Clones		
1st Clonal Trial 10′×10′		
ACU85	11	1,350
S27	11	1,150
A46	11	1,140
K5	11	1,100
2nd Clonal Trial 8′×8′		
ICS7	9·5	1,660
R15	9·5	1,650
D70	9·5	1,610
E9	9·5	1,435
New crosses		
8th Progeny Trial 8′×8′		
WAE5	6	1,070
WBE3	6	875
WE4	6	805
WE3	6	790
9th Progeny Trial 10′×10′		
WEB2	4	1,060
WAE11	4	1,060
WEB1	4	935

* Based on the wet to dry weight conversion ratio assessed for the selection (see p. 50). All other yields are calculated by presuming a conversion ratio of 40%

Yields from eight of the 'local hybrid' selections in the 1st and 2nd Clonal Trials are also included in Table 16. In the 1st Clonal Trial black-pod disease was allowed to develop unchecked, and infected pods recorded. Losses due to the disease varied according to the variety from less than 15 per cent. to over 50 per cent. The yields given in the Table include what should have been obtained if all the diseased pods were usable.

The 8th Progeny Trial, planted in 1952, has shown a small increase in yield. Selection WAE5, a cross between an Upper Amazon and an Amelonado, which gave 850 lb. per acre last year, is estimated to have yielded over 1,000 lb. per acre this year (see Table 16).

The selections in the 9th Progeny Trial are now almost four years old, and are yielding well. The performances of the four best varieties are included in Table 16.

The production of further hybrids, intended ultimately to provide new varieties for issue to the farmers, has been stopped for the time being, for the hybrids under trial are giving very promising results and it seems unlikely that with our present knowledge we could achieve further improvements of any consequence. In preparation for a future hybridisation programme, however, investigations are continuing on hybrids produced by crossing parents representative of individual Amazon populations, such as Nanay, Parinari, etc. to local types and also by crossing inbred generations of local types with Amazons.

Two small trials have been planted at WACRI to investigate the variability and performance of the progenies of hybrids in the 9th Progeny Trial.

WET TO DRY COCOA CONVERSION RATIOS

Experiments have been carried out to determine the degree of variation between Upper-Amazon varieties in the quantity of dry cocoa obtained from a given quantity of wet cocoa. The cocoa was fermented in small heaps enclosed in plantain leaves, the size of the heap depending on the amount of material available. The fermentation period and the time between harvesting and breaking were also varied, as convenient, and these factors appeared to affect slightly the individual results obtained. Climatic conditions and degree of ripeness seemed also likely to be relevant.

The conversion ratio was calculated from the total weights involved, and also from the ratio of average bean weights before and after fermentation as determined from samples. The former would be affected by any losses of beans during the fermentation and drying process, while the latter would be liable to sampling fluctuations. In practice the two ratios generally showed close agreement, and the

results given in Table 17, which shows the ratios obtained from different fermentations, are based on the average of the two estimates in each case. Intra-varietal variation can be attributed in part at least to variation in the fermentation period and other factors mentioned above. Insufficient data are available at present to determine significant differences.

TABLE 17

Wet to dry cocoa conversion ratios

Type	*Variety*	*Conversion ratios** (% *dry wt./wet wt.*)
Scavina × ?	T12	34, 36, 35
Parinari × Parinari	T86	33, 38, 37
Nanay × Nanay	T61	46, 44
	T62	45
	T81	41, 47
	T92	41, 40
Nanay × ?	T11	37, 42, 41
	T15	41, 41
Iquitos × ?	T17	40
Nanay × Parinari	T60	44, 40
	T63	40, 38
	T76	40, 37
	T79	45, 41
	T82	39, 37
Nanay × Iquitos	T72	40, 39
	T73	42, 40
	T85	39
	T87	40, 38
Parinari × Iquitos	T65	40, 38, 39

*Each rate was obtained from one fermentation.

The results show a considerable variation, from the low conversion ratios of selections T12 and T86 to the higher ratios of the pure-bred Nanays. In the past, when assessing the relative performances of different varieties an average conversion ratio has been applied, but it would seem advisable to use a ratio appropriate to the particular selection where possible.

NATURAL POLLINATION

Data from the 2nd Albino Plot are now available for the two seasons 1956–57 and 1957–58. This plot, established in 1952, consists of a square thirteen trees by thirteen, planted with an Amelonado clone which when selfed gives on average one albino seedling to three normal seedlings, but when outcrossed to other cacao gives only normal seedlings. As with the 1st Albino Plot (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 53) the results are complicated by the fact that some pods include a much smaller number of albinos than would be expected from the 1 :3 ratio. This effect could arise if the flowers were

pollinated twice, once from inside and once from outside the plot, or, more probably, it may be due to mixed pollination, as might occur through an insect carrying pollen from both inside and outside the plot. In preparing Table 18 these mixed pollinations have been regarded alternatively as from inside (first and smaller figure) or from outside the plot (second, and higher figure).

TABLE 18

Albino plot pollinations

	Estimated percentage pollination from outside the plot in row				
	1 (*outer*)	2	3	4	5+6+7 (*inner*)
1956–57	47–56	46–53	35–49	32–57	30–60
1957–58	42–53	50–63	50–58	30–36	37–49

Even in the centre of the plot, separated from normal cacao by five or six rows of trees, there is a substantial proportion of pollination from outside the plot. In applying these results to the design of seed gardens it must be remembered that the plot is relatively small, and also that the cacao is young and is not flowering as freely as the surrounding cacao. However, it would appear that wide guard rows will be necessary if reasonably pure seed is to be obtained.

PHYSIOLOGY OF FRUITING

(R. G. Hurd)

FACTORS INFLUENCING YIELD

Detailed recording on selection ACU85 in the 1st Clonal Trial has been continued, and some interesting points with regard to the factors controlling the timing of the crop have emerged.

During the past four years the start of the rainy season has varied over a period of about two months, and it has been observed that the major flush of the year follows some three to four weeks later (see Table 19). This flush coincides exactly with the first major flowering peak of the year, the so-called 'crazy flowering'. The flowering peak which is associated with the final crop follows the first by an interval of about eight weeks, and this in turn is followed by a harvesting peak twenty-three or twenty-four weeks later. Thus, for this selection growing under the particular conditions involved, it is possible to forecast that the peak of the harvest will be about thirty-five weeks after the onset of the rains.

TABLE 19

Time intervals between rains and harvesting

Year	*Start of rainy season*	*Interval to major flush (days)*	*Major flush to 'crazy flowering' (days)*	*'Crazy flowering' to Main flowering (weeks)*	*Main flowering to Harvest peak (weeks)*	*Rains to Harvest peak (weeks)*
1955	16th Feb.	28	5	6½	23	34
1956	9th Mar.	24	0	8½	24	36
1957	9th Apr.	23	1	8	23	34
1958	27th Feb.	26	5	—	—	—

Similar observations on Amelonado cacao in the course of other experiments suggest a similar association of flushing and flowering with the start of the rains, but the total period between the rains and the peak of the harvest is more variable in most cases.

Cherelle wilt in the Trinidad Introductions

The results recorded during this season support the conclusion indicated by those recorded last year (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 60) that there is no relation between percentage wilt and yield. The average wilt for the trial was again 75 per cent., while wilts for the five best selections, in order T12, T28, T86, A164 and T82, were 64, 66, 71, 78 and 80 per cent. respectively. Although these figures show an increase in wilt with decreasing yield, several other varieties with low percentage wilt have low yields. Selection T12 has had during the past two seasons the lowest wilt of any selection, i.e. 66 and 64 per cent. in the two years, and has also given the highest yields. There is a general indication that for a given selection the percentage wilt does not vary greatly from year to year, which suggests the possibility of breeding for low wilt.

EFFECT OF GIBBERELLIC ACID ON CACAO SEEDLINGS AND CUTTINGS

Preliminary experiments have been carried out on the effect of gibberellic acid on the growth of cacao seedlings and cuttings.

Effect on seedlings

Quantities of gibberellic acid ranging from 1 to 100 μg., contained in small drops (0.0125 ml.) of aqueous solution were applied to the growing points of four-week-old seedlings. Eighteen seedlings were used per treatment and the increases in stem length, as a percentage of pretreatment length, are given in Table 20. The application of 5 μg. gave the maximum response, although both the 10 and 100 μg. treatments were almost equally effective. With the exception of plants treated with 1 μg., which resumed a normal rate of growth after two

weeks, the treatments stimulated growth for a period of five weeks. During this time the leaves produced were smaller and narrower than normal, but there was a definite increase in the number of leaves.

TABLE 20

Effect of gibberellic acid on seedlings

Quantity of gibberellic acid applied	*Percentage increase in stem length*								
	4 *days*	1	2	3	4	5	6	7	13
				weeks after treatment					
Nil (control)	11	12	15	16±3	18	22	24	29±4	63
1μg.	25	49	71	72±7	84	91	92	95±7	116
5μg.	24	66	114	164±10	190	191	193	194±12	198
10μg.	26	53	89	136±11	164	175	176	178±13	182
100μg.	29	57	80	115±12	135	147	150	156±21	190

Effect on cuttings

As with seedlings, varying quantities of gibberellic acid were applied to the growing points of ten-week-old fan cuttings. Table 21 shows the average increase in length of the main stem, as a percentage of pre-treatment length, for the eighteen cuttings used per treatment. In general the treated plants have increased more than the controls, and the difference between the control and the 10 μg. treatment after four weeks is highly significant. The response is however very much smaller than that obtained with seedlings.

TABLE 21

Effect of gibberellic acid on cuttings

Quantity of gibberellic acid applied	*Percentage increase in stem length*			
	2	4	6	8
		weeks after treatment		
Nil (control)	19±8	58	68±12	84
1μg.	34±8	86	94±14	115
5μg.	24±5	52	83±12	88
10μg.	39±11	92	93±9	116
100μg.	39±9	79	92±12	112

VEGETATIVE PROPAGATION

(R. G. Hurd)

ROOTING UNDER POLYTHENE SHEET

Most of the cacao selections grown at WACRI can be satisfactorily propagated using the polythene sheet method, with a degree of success varying from 60 per cent. upwards. Some selections, however, have proved difficult, and with these only 20–30 per cent. success

can normally be expected. In an attempt to improve results with these types, further experiments have been carried out on the choice of planting material, rooting and hardening conditions, and rooting hormone treatment.

Choice of planting material

For successful results cuttings should be taken from healthy fan branches on young trees, preferably during the wet season. The position on the branch is also important, and several experiments have indicated that the best material is obtainable from between the fourth and twelfth leaves, counting from the apex.

Rooting conditions

In previous work (*Rep. W. Afr. Cocoa Res. Inst.*, 1950–51, p. 28) it has been shown that a mixture of sand and rotting palm fibre is the best medium for rooting cuttings. A 50:50 mixture has normally been used, but tests have now been carried out on a poor rooting selection using mixtures containing 25 and 75 per cent. sand. The results, given in Table 22, show that the 50:50 mixture is the most satisfactory and it seems unlikely that intermediate mixtures could lead to any great improvement.

TABLE 22

Effect of rooting medium composition on rooting

	Composition of rooting medium Palm fibre/sand ratio		
	25:75	50:50	75:25
Number rooted	42	67	34
Number of roots per cutting ..	2.6±0.49	4.65±0.43	2.8±0.53

Note: 120 cuttings per treatment

The rooting medium must be kept reasonably moist, and cuttings are usually watered every three days, although less frequent watering is required during the wet season. Further experiments on the degree of watering appear to be unwarranted.

With poor rooting selections shade conditions considerably affect the number of cuttings which root, and also their subsequent rate of growth. Both an easily rooted clone, S27, and a clone which is difficult to root, A72, have been used in an experiment to compare the effects of exposure to 10 per cent. sunlight and 25 per cent. sunlight, with exposure to 10 per cent. sunlight during the first fortnight after setting followed by 25 per cent. sunlight thereafter. The cuttings were shaded with palm frond matting and the light intensities given are based on the proportion of the mat area through which sunlight

could pass. The results are presented in Table 23. Taking into account root growth the third treatment involving both 10 and 25 per cent. sunlight appears to be most effective. In this experiment the cuttings were moved from the lower to the higher light conditions but in practice this result could be more simply achieved by keeping the cuttings under 25 per cent. light conditions for the whole period, and covering them with a suitable translucent material for the first fortnight.

TABLE 23

Effect of shade on rooting

Percentage sunlight	*Number of cuttings successfully hardened*		*Average length of new shoot after 12 weeks (cm.)*	
	Clone S27	*Clone A72*	*Clone S27*	*Clone A72*
10	78	65	4.8	2.5
25	77	15	8.2	4.8
10/25	79	38	8.1	6.4

Note: 80 cuttings per treatment

The intensities quoted above refer to the light over the polythene sheet, and they do not take into account the light absorbed by the sheet. With the 0.0015 in. sheet, which was previously used, transmission is approximately 83 per cent of incident light, while with 0.005 in. sheet about 73 per cent. of incident light is transmitted. In comparative experiments the percentage of cuttings successfully rooted was slightly lower with the thicker grade, but this has a much longer life under rough usage. The intermediate 0.003 in. polythene sheet is now used for all routine work.

With poor rooting selections root formation may be delayed for several weeks, and the application of a fungicide to the end of the cutting is being investigated to prevent rotting during this period.

Rooting hormone treatment

The most useful rooting hormone, and its optimal concentration, have been established in previous work. Further experiments have shown that a second application of hormone gives beneficial results. Table 24 shows the results obtained in one experiment, where four treatments were applied, each to ninety cuttings. The normal procedure of dipping the cuttings into β-indole butyric acid just before setting was used as a control, while the other treatments consisted of (*a*) two applications of hormone, the first at setting and the second two weeks later, (*b*) hormone application to both ends of the stem of the cutting at setting, and (*c*) ringing the petioles of the leaves. The latter treatment has been previously recommended but had no

advantageous effects. Double application of the hormone, however, whether as treatment (*a*) or (*b*), significantly increased the number of cuttings rooted, and the number of roots per cutting.

TABLE 24

Effect of different hormone treatments on rooting

	Percentage of cuttings rooting	*Number of roots per cutting*
Single application of hormone (control) ..	27.8±5.2	3.16±0.59
Double application of hormone with two weeks interval	50.0±8.0	3.87±0.53
Hormone application to both ends of cutting	52.3±8.6	4.38±0.59
Petioles ring-barked	28.9±7.9	2.20±0.66

Stem diameter of the cutting

Observations on poor rooting selections have suggested that ease of rooting may be related to stem diameter, but on careful investigation this has not been substantiated (Table 25). As indicated above cuttings are best taken from between the fourth and twelfth leaves on a branch. On cuttings taken within these limits from a particular clone there is no apparent relationship between stem diameter and either the number of cuttings successfully rooted or the number of roots formed per cutting. The better rooting selections appear to have slightly thicker stems, although the difference is not statistically significant, and also produce more roots per cutting, as shown in Table 25.

TABLE 25

Effect on rooting of the position of the cutting on the parent branch

Selection	*Ease of rooting*	*Position of cutting on parent branch as leaf number from apex*													
		2/3		4/5		6/7		8/9		10/11		12/13		14/15	
		A	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*	*A*	*B*
R15	Good	18	6.5	20	8.4	20	7.5	20	8.0	18	6.2	19	9.0	17	11.4
SC1	Inter-	13	4.3	14	5.1	15	3.6	13	5.4	12	6.8	12	5.2	12	7.1
T17	mediate	5	3.8	13	5.5	13	4.8	17	4.8	17	5.3	7	4.7	10	5.3
A196	Poor	4	3.0	3	6.3	4	6.5	1	10.0	2	6.5	0	0.0	0	0.0

A. Number of cuttings rooted
B. Average number of roots per cutting
Twenty cuttings per treatment

TRANSPORTATION OF CUTTINGS

Cuttings which are beginning to show signs of rooting may be washed free from soil without harm. Attempts have been made to develop a convenient technique for the transportation of clean cuttings of this sort, so as to avoid the contravention of phytosanitary regulations regarding the importation of soil when sending planting material to neighbouring territories.

The following method appears to be satisfactory. The cuttings are set in the rooting medium in the normal way, and are lifted when root formation has just started. This may take from two to four weeks, the time varying considerably even within a batch of cuttings; but it does not seem to be critical as cuttings at any stage between basal swelling and the formation of a few roots may be taken. After careful washing the cuttings are packed in cellophane bags, which are sealed with 'sellotape'. The bags used are 12 × 18 in., and are made up of two layers of cellophane with a blotting paper lining. A bag of this size will hold ten cuttings. To maintain a high humidity 100 ml. of water are added to each bag, and several bags are then packed into a wooden box, suitably ventilated. After transportation, the cuttings are removed and are re-inserted into baskets, according to the normal procedure, after a second dip in rooting hormone. After forty-eight hours in very hot conditions, packed cuttings have survived quite satisfactorily, with an average of about 75 per cent. successful rooting after this treatment.

SOIL FERTILITY, SHADE, AND MANURIAL REQUIREMENTS

ABSORPTION AND TRANSLOCATION OF RADIOACTIVE PHOSPHORUS (R. G. Hurd)

The experiment on phosphate uptake by four-year-old unshaded Upper-Amazon cacao trees has now yielded results for a complete year. Throughout the year four trees in the plot have been selected at random each month and a solution of radioactive phosphoric acid has been applied to the soil around the trees. From an analysis of the radioactivity in the aerial parts of each tree ten days later the percentage of applied phosphate taken up by the tree can be estimated; the results are presented in Table 26. To correct for girth variations the figures have been adjusted to a common diameter of 8 cm. (the mean diameter of the treated trees), and the corrected data are also included in the Table.

The figures given for the first four months differ slightly from those quoted in the previous Annual Report because accurate corrections for self-absorption were not then available.

The variation is too large to establish significant differences but an apparent general trend can be distinguished, showing that uptake tends to a maximum in June and then falls to a minimum in March. From the rainfall data given in the Table it may be seen that the sharp rise in April coincided with the onset of the rains. For the whole year the correlation coefficient of 0.7 for uptake and rainfall was significant, and uptake is also closely related to the number of wet days

TABLE 26

Percentage uptake of P^{32} and rainfall

Month	*Percentage uptake*		*Rainfall (in.)*	*No. of wet days during uptake*
	Unadjusted	*Adjusted for girth*		
December 1956	2.2	5.1±0.4	3.3	1
January 1957	3.3	5.1±0.8	1.3	2
February	3.3	4.5±2.1	2.8	1
March	1.1	1.3±0.3	1.5	3
April	5.9	8.2±3.7	11.3	7
May	4.5	7.0±3.4	8.3	6
June	8.5	12.8±3.5	10.4	10
July	9.0	8.7±2.6	15.4	9
August	5.6	7.6±1.5	2.0	7
September	4.5	5.8±2.4	4.8	7
October	3.2	3.8±2.2	5.1	5
November	4.8	3.2±0.9	3.7	5
December	2.2	2.6±0.5	2.7	3

during the ten days from application to analysis. Soil moistures, which were recorded during the latter half of the experiment, followed closely the rainfall figures. The main April flush coincided with a period of high uptake, but none of the other flushes showed a similar association. During the period of the main crop over July and August, uptake was falling.

Variation in uptake may be attributed to a number of causes but these are unimportant from the practical point of view, and assuming that the uptake of fertilizer varies in a similar way to that of P^{32}, it would appear that nutrients should preferably be applied between April and August. During this period the flowers destined to produce the main crop set and develop.

Most of the roots of the cacao tree are within 1–3 in. of the soil surface, and they extend over a wide area. This would suggest that fertilizers should be broadcast uniformly over the whole area, and this method is being followed in the fertilizer trials.

EFFECT OF MAJOR NUTRIENTS ON CACAO (R. K. Cunningham)

Trials on Amelonado cacao

The 2^2 'N-P' and 'K-Magnesian limestone' factorial experiments on irregularly planted mature Amelonado cacao (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 67) have been continued. Following the first year of fertilizer application no significant responses were obtained, but there were indications of beneficial effects at all sites.

A large Shade and Manurial Trial was started at WACRI in 1956. The Trial covers an area of $7\frac{1}{2}$ acres, and consists of Amelonado cacao planted in lines at 8×8 ft. in 1947. The area was clear-felled before planting, and the cacao was established under temporary shade provided by tree cassava and bananas. *Gliricidia* trees were planted as

permanent shade, initially at 8×8 ft. but later thinned to 24×24 ft.

Four main treatments have been applied, *viz.* (*a*) shade, without fertilizer, (*b*) shade, with fertilizer, (*c*) no shade, without fertilizer, and (*d*) no shade, with fertilizer. For the unshaded plots the *Gliricidia* trees were poisoned with 'Phortox' in March 1957. Each treatment involves 900 trees (three replicates of 300). The yields for 1957–58 are given in Table 27, together with pre-treatment yields and details of the fertilizer applications made to date.

TABLE 27

Shade and manurial trial

Pre-treatment yields (lb. dry cocoa per acre)			*Treatments*	*Yields for* 1957–58
1954–55	1955–56	1956–57		(1/4/57–31/3/58)
30	44	205	Shade without fertilizer	615
24	32	211	Shade with fertilizer*	868
19	29	170	Shade removed only	1,080
20	18	173	Shade removed, fertilizer* applied	1,576

* Fertilizer applied to date:

Oct. 1956	Ammonium Phosphate } Single Superphosphate }	N—13.4 lb./acre P_2O_5—90.7 lb./acre
	Sulphate of Potash	K_2O—90.4 lb./acre
	Magnesium Sulphate	MgO—45.8 lb./acre
April 1957	Urea	N—50 lb./acre
	Triple Superphosphate	P_2O_5—30 lb./acre
Sept. 1957	Urea	N—50 lb./acre

An analysis of covariance has been carried out, and it should be noted that the figures given in the Table are actual recorded yields, and not adjusted yields. The results show that:

(*a*) the effect of shade removal together with fertilizer mixture application is highly significant (P=.001);

(*b*) on plots treated with fertilizer the effect of shade removal is highly significant (P=.001);

(*c*) on plots not treated with fertilizer the effect of shade removal is very significant (P=.01);

(*d*) on unshaded plots the effect of fertilizer is very significant (P=.01);

(*e*) on shaded plots the effect of fertilizer is significant (P=.05).

An experiment to compare various rates of application of N, P, K and Mg is being laid down on 10 acres of Amelonado cacao, growing under conditions similar to those of the Shade and Manurial Trial.

Trials on Amazon cacao

A 2^4 NPKMg factorial experiment has been started at Bunso on 6½ acres of F2 Amazon cacao planted as basketted seedlings in 1956.

Girth measurements were taken six months after the first application of fertilizer and all elements showed beneficial effects.

An Amazon seedling establishment experiment was started in July 1957 on soil which had been exposed for a considerable time. A Guatemala grass mulch and an NPKMg fertilizer mixture were applied separately and together, with a nil treatment control, and girth measurements taken four months later showed significant responses to both mulch and fertilizer.

EFFECT OF MINOR ELEMENTS ON CACAO (R. K. Cunningham)

An experiment has been set up, in conjunction with the Pathology Division, to detect any nutrient effects of copper fungicidal sprays. The treatments include pod-spraying with carbide-bordeaux and with Perenox, and the application of copper sulphate to the soil and to the canopy.

Cacao growing on a small area at WACRI appears to suffer from manganese, zinc and iron deficiencies. Comprehensive analyses of soil samples and leaves from the affected area are being carried out.

COCOA PREPARATION AND QUALITY

FERMENTATION (T. A. Rohan)

The detailed study of the lack of uniformity in heap fermentation (*Rep. W. Afr. Cacao Res. Inst.*, 1956–57, p. 68) has been completed and a brief summary of the salient points is given below. A full report on this work is given in the *Journal of the Science of Food and Agriculture*.

When West African Amelonado cocoa is fermented in heaps there is a marked lack of uniformity in the rates at which the changes associated with fermentation occur throughout the mass. The temperature in the outer 4 in. rises more rapidly than that at the centre and the beans in this surface layer are killed more quickly. Cocoa flavour appears to develop much more quickly than the literature suggests is possible and the beans can be removed from the surface layer for drying within twelve hours of death. A product unofficially considered by competent tasters to be within the acceptable range has been obtained after thirty hours fermentation at the surface of a heap of fermenting cocoa. The beans at the centre of the heap were killed more slowly, the rate depending on the size of the heap. When these centre beans had died, however, the development of cocoa flavour was as rapid as in the surface layer. In the largest heaps the beans at the centre were dead by the third day and death could be accelerated to some extent by mixing. Beans were killed at a more uniform rate the smaller the heap; but there was a lower limit below which heat losses offset this effect. It has been suggested that the optimum weight

of cocoa suitable for heap fermentation is of the order of 500 lb., and work on the 1957–58 main crop has indicated that batches of this size can be properly fermented (as assessed visually and by unofficial tasters) in four days without mixing, though mixing after twenty-four hours reduces the risk of the surface beans drying out. Under favourable conditions the size of heap can be reduced, and heaps of 150 lb. wet cocoa have been properly fermented (as judged by bean colour and unofficial tasting) in four days with one mixing after twenty-four hours. Batches of this size are considered suitable for experimental purposes.

Mixing is not essential in promoting the death of the beans, but in large heaps beans die more quickly when mixed. Mixing is, however, advisable with all sizes of heap to prevent drying out of the surface beans.

Changes accompanying fermentation in sweat boxes, as compared with those in heaps, are much slower due to the lack of aeration. This can be corrected to some extent by earlier mixing, and in sweat-box fermentation, it may be preferable to mix the bean mass after twenty-four and forty-eight hours, instead of the customary forty-eight and ninety-six hours. This leads to a sharper temperature rise.

Although recent results indicate that six days fermentation may be unnecessarily long for West African Amelonado cocoa, it must be emphasised that the removal of beans for drying should be based largely on the internal appearance of the cotyledons as assessed by an experienced operator, rather than on a rigid set of conditions regarding time and frequency of mixing. Until the fermentation process can be more accurately controlled it would be unwise to recommend a standard, inflexible set of conditions.

The surface effect observed in heap fermentation suggested that, under favourable conditions, it might be possible to ferment West African Amelonado cocoa in much shorter times than those normally recommended. Experiments were carried out using a rotating stainless-steel drum in a solar fermentary, and an acceptable product was prepared after some twenty-four hours fermentation, the beans having been killed in six hours. Using 4-in. layers of cocoa beans in special trays an acceptable product (unofficial assessment) was obtained after two days fermentation, and the results were sufficiently encouraging to warrant large-scale trials of this method (see below).

Quantitative estimations were made of the anthocyanins and polyphenols, at different levels in the heap, during fermentation, and also after drying. The results emphasised the lack of uniformity in 'rate of fermentation' throughout the heap. Other general conclusions arising from this work may be summarised as follows:

(*a*) No change in concentration of anthocyanins or polyphenols

occurs before the death of the bean and liberation of these compounds from their storage cells.

(*b*) After the death of the bean, removal of the anthocyanins was rapid, and the rate independent of the position in the heap. This reaction was continued on the drying trays, and in some experiments very high concentrations of anthocyanins have been almost completely reduced after drying. If complete removal of the anthocyanins is to be effected, the beans must be completely dead before drying is started. Normally, when beans are dried before they are dead the product is slaty. Germination tests indicated that sometimes the death of the beans can occur during the initial stages of drying. For example, in a 600-lb. heap a sample of beans withdrawn from the top 4 in. after twenty-two hours fermentation showed 25 per cent. germination after planting, yet on drying there were no slaty beans. The presence of deep purple beans might also result from the passage of a proportion of live beans to the drying trays. These beans would die during the initial stage of drying and liberate the polyphenols from their storage cells. The moisture content of the cocoa would, at the same time, be decreasing and the minimum level for enzyme activity might be reached before complete destruction of the anthocyanins had been effected. It is extremely difficult to consider fermentation and drying as separate processes, as the one continues into the other.

(*c*) Beans withdrawn from the surface layer of a fermenting heap twelve hours after death have been found, in some experiments, to contain no higher residual anthocyanins concentration, after drying than beans fermented in the orthodox manner for six days.

(*d*) The existing method of classification of fermented beans by visual appearance of the cotyledons gives no clear definition of the expression 'purple beans'. An attempt was made to relate the internal appearance of the fermented and dried beans, the amount of residual pigment, and the quality. In several estimations of residual anthocyanin concentration in hand-picked purple beans of varying degrees of purple intensity, not more than 25 per cent. unchanged pigments were found in the deepest purple beans; the concentration of residual anthocyanins in beans of medium purple intensity was of the order of 15 per cent. of that in the fresh beans; and beans pale-purple/brown in section contained less than 10 per cent. Unofficial quality assessment of these main groups suggested a relationship between visual appearance, residual pigment and quality, as given in Table 28.

These results were obtained from random samples which showed that increasing residual anthocyanin concentration is associated with the appearance of slatiness. Deep purple beans could be tolerated up to 40 per cent. of the total provided no slatiness was present. Since these beans contain approximately 25 per cent. unchanged pigment

TABLE 28

Relationship between anthocyanin concentration appearance and quality of dried beans

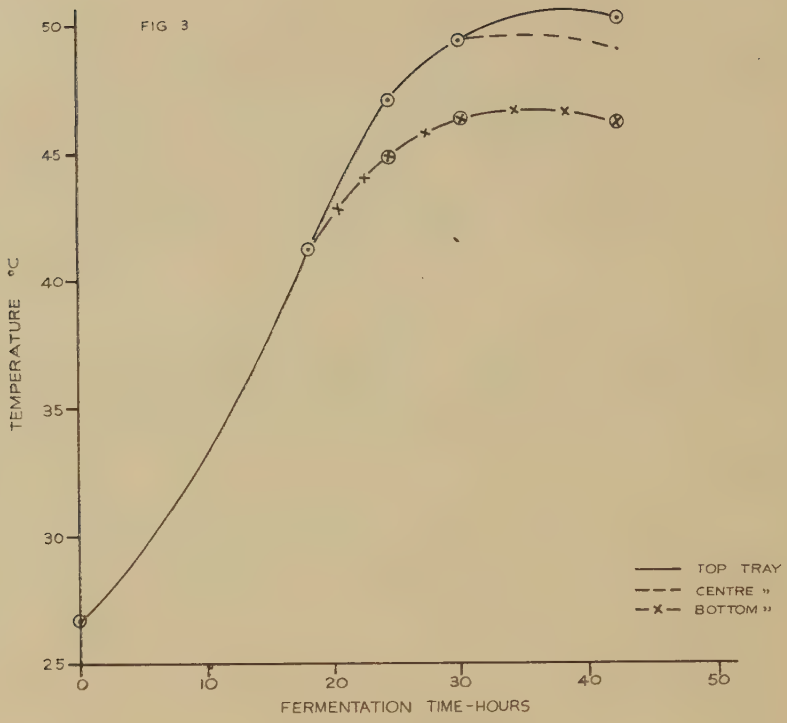
Anthocynanin concentration as % of that in fresh cocoa	*Appearance of cotyledons*	*Quality*
0–10	Pale purple/brown	Acceptable
10–20	Brown with deep purple	Borderline
20–30	Purple with slate	Unacceptable
30–100	Increasing slate	Unacceptable

the total residual pigment in a sample containing 40 per cent. of such beans would be of the order of 10 per cent. of that present in the fresh beans; this is shown above to be within the range of acceptability. The results suggest a tolerance to deep purple greater than previously suspected.

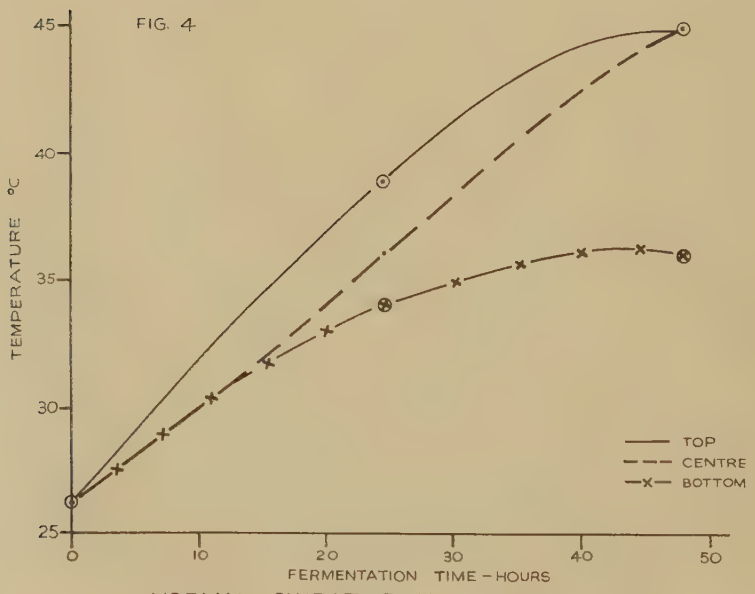
(*e*) The quality of fermented West African Amelonado cocoa appeared to be more closely related to the concentration of residual anthocyanins than to that of the other polyphenols. As much as 60 per cent. unchanged polyphenols could be tolerated without adverse effect; while the upper limit for anthocyanins was more closely defined at about 10–15 per cent. of the concentration in fresh beans.

A NEW TECHNIQUE FOR BULK FERMENTATION OF WEST AFRICAN AMELONADO COCOA (T. A. Rohan and H. W. S. Allison)

As mentioned above, the success achieved in the fermentation of 4-in. layers of Amelonado cocoa beans in trays justified experimentation on a larger scale. Trays 4 ft. × 3 ft. × 4 in. deep were made in *Chlorophora excelsa* wood with bottoms of the slatted matting used for drying mats. Numerous experiments were made in which the number of trays, the method of stacking these trays, the method of heat insulation and the duration of fermentation, were varied. Temperature measurements were made and the beans examined at regular intervals. The method of fermentation finally adopted was to fill one half of each tray (see below) with wet cocoa to a depth of 4 in. and to stack the trays (five to twelve in number) so that the filled sections were placed directly above each other. The top tray only was covered with plantain leaves and after twenty-four hours the stack was covered completely with a close-fitting sacking cover and fermentation continued for a further twenty-four to forty-eight hours. Figure 3 shows the remarkably rapid and uniform temperature rise obtained in a typical fermentation employing five trays, each containing 200 lb. wet cocoa.



TRAY FERMENTATION



NORMAL SWEAT-BOX FERMENTATION

Figure 4 shows the time/temperature curves at comparable levels in a normal sweat box fermentation.

The method described above of filling only half the fermentation tray was employed to facilitate drying. Though beans can be fermented rapidly in 4-in. layers this is too deep for successful drying. On the other hand 2-in. layers dry well but ferment unsatisfactorily. In order, therefore, to have the optimum depth for both fermentation and drying the trays were fitted with removable partitions and one-half of each tray filled to a depth of 4 in. with beans. After fermentation the partition was removed, and the cocoa spread to a depth of 2 in. for drying.

This new technique reduces handling to a minimum as the fermenting beans are not mixed and they are dried *in situ*. A calculation of costs has shown a saving of at least 16 per cent. in man-hours, compared with orthodox methods. Preliminary quality tests have indicated that the method may yield a product within the range of acceptability for West African Amelonado cocoa.

STUDIES ON CACAO ENZYMES (E. Margaret Holden)

During the 1957 main crop season further investigations on the rate of inactivation of several enzymes during fermentation were made, using heaps varying in size from 200 to 2,000 lb. wet weight of beans. Temperatures at different levels in the heaps were recorded and samples of beans were removed after various periods of fermentation. Enzyme determinations were made using acetone-powders prepared from a portion of the sample. Other portions were used for estimating the anthocyanin concentration and for measuring the pH of an aqueous extract of the cotyledons; germination tests were also carried out and part of each sample was sun-dried. Counts of slaty and purple beans were made on the dried beans and chocolate was made from a number of the samples which had been fermented for more than two days.

In the top of the heap beans were usually dead eighteen hours after the start of fermentation and there was little change in the enzyme activities. During the twenty-four hours following the death of the beans enzyme levels fell rapidly until after four days from the start there was little or none of most enzymes detectable. The changes took place rather more slowly in the centre of the heap where the temperature rise was not so rapid, but even with large heaps which were not turned there was little difference between beans from the top and centre after four day's fermentation. Polyphenol oxidase, which is assumed to be responsible for the catalysis of the oxidative changes in the polyphenols that take place during drying, appeared to be reduced to less than 10 per cent. of its original level in beans

fermented for four days, when determined by a colorimetric method. Further work on this enzyme using manometric methods should show whether in fact these changes are due to enzyme action or simply to autoxidation when conditions become suitable.

A paper on enzymic aspects of fermentation describing this work in more detail will be submitted to the *Journal of the Science of Food and Agriculture*.

Germination inhibitor

The pulp of beans was found to contain a germination inhibitor which, under normal conditions of fermentation, will effectively prevent germination taking place. The inhibitor can be removed by washing the beans, which then germinate much more rapidly than unwashed beans particularly when kept at a temperature of 36°C. Washed beans kept at 36°C. were not killed as rapidly as those incubated in the presence of pulp. The inhibitor appears to be broken down fairly rapidly by micro-organisms as beans normally germinate in about a week at air temperature whereas Archibald (*Rep. W. Afr. Cocoa Res. Inst.*, 1953–54, p. 23) found that under sterile conditions germination is delayed for as much as a fortnight longer.

Aqueous extracts of pulp at the normal acid pH, or after neutralisation, inhibit the germination of mustard seeds. This was used as the basis of a test for comparing the concentration of inhibitor in pods of different degrees of maturity. The pulp of fully grown unripe pods had almost ten times as much inhibitor as the pulp of slightly overripe pods. Acetone extracts of pulp were chromatographed in an attempt to separate the inhibitor, but no useful results were obtained. Little is known of the effect of germination inhibitors on enzymes, but it is reasonable to suppose that they will inhibit enzymic reactions concerned with germination changes. If the inhibitor in cacao pulp has such an inhibitory effect on enzyme systems the theory that during the early stages of fermentation some of the preliminary stages of germination take place may no longer be tenable. Rapid killing of beans by exposure to temperatures which do not cause immediate inactivation of all the enzymes, followed by a period at the usual temperature reached during fermentation, results in a well-fermented product.

IBADAN SUB-STATION
VIRUS RESEARCH

STRAINS OF NIGERIAN CACAO VIRUSES (T. W. Tinsley and J. M. Thresh)

Several experiments in Ghana and in Nigeria have indicated that

different trees within a limited area may contain viruses which differ considerably in virulence and in the symptoms they cause. It is possible that cacao viruses are particularly unstable and are continually giving rise to new forms which become segregated during normal spread. Alternatively the mealybugs may carry more than one form of virus from outside sources of infection when starting new outbreaks. To elucidate this point studies are being made of the range of viruses present in very small outbreaks or in single naturally-infected trees surrounded by healthy cacao.

In attempts to discover mild strains of some of the Nigerian cacao viruses, several isolates have been obtained which have little effect on the growth of cacao and which produce only transient or inconspicuous symptoms and no swellings on the aerial parts. Experiments are now in progress on some of these viruses to determine their ability to protect plants from the effects of subsequent inoculation with a range of virulent viruses from various localities.

Nine isolates of mild virus have been obtained from trees showing inconspicuous and infrequent symptoms in the Koroboto Observation plot in the Ibadan area of mass infection. Plants infected in transmission tests from them caused mild symptoms on seedlings infected by grafts or by insects, and further transmissions are being carried out from the most vigorous of these plants in an attempt to obtain particularly mild forms of virus. Similar mild viruses have been obtained from all the outbreaks investigated in detail, including ones at Aladie in Ilaro Province, and others at Balogun and Ikire in Ibadan Province. One isolate from Ikire gave very mild symptoms, and infected plants had an average leaf area of 876 sq. cm. after sixteen weeks, compared with an area of 916 sq. cm. on healthy controls, and 436 sq. cm. on plants infected with the normal virus from Ikire.

THE CONTROL OF CACAO SWOLLEN-SHOOT VIRUS IN NIGERIA

(T. W. Tinsley and J. M. Thresh)

Further results from the coppicing experiments on naturally occurring outbreaks of swollen-shoot virus (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 81) are now available and they confirm the earlier analysis.

The number of infected stumps occurring around the treated outbreaks decreased sharply with increasing distance from the infected trees cut out at the time of coppicing. Of the infected stumps found within 30 yards of these trees, 51 per cent. were within 5 yards, 35 per cent. between 5 and 10 yards, 8 per cent. between 10 and 15 yards, and the remaining 6 per cent. between 15 and 30 yards. This steep gradient is consistent with the suggestion that most of the

spread of the virus takes place by the movement of mealybugs for a limited distance through the cacao canopy and to a much lesser extent by the wind-borne spread of mealybugs through the air. The latter is, however, probably responsible for 'jump spread', when infection appears some distance from a virus source. The occurrence of 0.4 per cent. infection among trees between 25 and 30 yards from centres of infection in the coppicing experiment indicate that significant amounts of spread may take place over considerably greater distances.

The distribution of infected stumps within the 30 yard radius was similar for outbreaks of all sizes, but the intensity of infection varied from 4 per cent. of stumps around outbreaks of more than fifty infected trees, to 0.7 per cent. around the smallest outbreaks. As many of the coppiced stumps failed to regenerate these figures are underestimates and actual intensities may be up to twice as high. Even then, however, there seems little justification for treating all outbreaks, regardless of size, to a distance of 30 yards. With the modified techniques which have been recommended, where apparently healthy trees are cut out to a distance of 5 yards from outbreaks of less than six infected trees, 10 yards for six to fifty infected trees, and 15 yards for larger outbreaks, the corrected data indicate that the intensity of latent and missed infection in the adjacent trees will not, on average, exceed 5 per cent. It is considered more economical to rely on these infections being found by the survey parties during re-inspection rather than to attempt to eradicate them by more drastic initial treatment methods.

INSECT TRANSMISSION OF CACAO VIRUSES (C. K. H. Martini)

The virus isolate from Asalu in Nigeria, for which the name 'cacao necrosis virus' has been proposed (*Rep. W. Afr. Cocoa Res. Inst.*, 1956–57, p. 72), has so far not been transmitted experimentally by mealybugs. Further experiments are in progress, and other insects occurring on cacao and on cola are being tested for their ability to transmit the virus. Tests have included the aphids *Toxoptera citricidus* Kirkaldy, *T. aurantii* B.d.F., the cacao psyllid *Tyora tessmanni* Aulm., and the mealybug *Ferrisiana virgata* (Ckll.), but no transmissions have been recorded. Cacao necrosis virus occurs in the main cola growing areas and the susceptibility of *Cola* spp. to this virus is being investigated.

Transmission tests with single insects have been started using test-plants infected simultaneously with isolates from Elepo and Alaparun. These tests should provide more data on the availability of virus in plants and possible selective transmission by the species used. Experiments have been started on the problem of virus complexes using

single insect transfers and it is hoped that this will be of use in the work on strain relationships.

STUDIES ON 'DIE-BACK' OF CACAO

(D. Kay)

Effect of 'die-back' on regeneration

During experiments on coppicing it was found that trees which were alive at the base only, gave the lowest percentage regeneration. In some of these trees an area of 'die-back' had extended below the line of coppicing and fungal infection was active within the coppiced stump. It was not possible to separate, in the analysis, deaths due to fungal damage from those due to a loss of vigour of trees alive at the base only, and an experiment has been started to determine the effect of the die-back fungus, *Fusarium decemcellulare*, on regeneration. A preliminary experiment in which ninety coppiced stumps were infected with fungus during the wet season (June) proved unsatisfactory as *F. decemcellulare* could subsequently be recovered from only a small proportion of the coppiced stumps. In this case subsequent regeneration appeared normal on both infected and uninfected stumps. With a modified method of infection a further ninety trees were coppiced in the dry season (December) and infected with pure strains of laboratory cultures of *F. decemcellulare*. No results are yet available, but chupons are developing rapidly on most of the stumps.

Existing areas of 'die-back'

An experiment has been started on three plots of farmers' cacao at Araromi, Western Region, to compare the rate of increase of existing areas of 'die-back' in trees treated with insecticides to control capsids with that on untreated trees. One of the plots had received 4 oz, *gamma*-BHC (as Gammalin 20) per acre applied with a mistblower at monthly intervals from August 1956 to February 1957. In the present experiment this plot was treated with 4 oz. *gamma*-BHC per acre at twenty-eight-day intervals, from August to October 1957 using a knapsack sprayer, while a second plot was treated with 40 per cent aldrin at 4 oz. toxicant per acre, again at twenty-eight-day intervals. The third plot was left untreated.

In each plot one hundred trees were selected to give a fair representation of the general condition of the plot and these trees were classified into five groups ranging from 'no canopy' to 'full canopy'. One thousand three hundred and forty-six areas of 'die-back' were marked on the 300 trees, and their increase in size was recorded monthly. There was considerable variation between plots in the percentage of areas which advanced, and the amount of advance.

In the control plot 16 per cent. of the areas increased each month, of which 72 per cent. advanced more than 6 in. Corresponding figures in the *gamma*-BHC treated plot were 8 and 57 per cent., and in the aldrin treated plot 10 and 51 per cent. respectively. The average increase overall was 6–10 in. per month, but some areas advanced as much as 80 in. Some areas increased during only one month, others during two successive months and a few during three successive months. The increase appeared to be independent of the initial size of the dead area, the general condition of the tree or the position of the marked area on the tree.

The presence of termites in areas of 'die-back'

A survey, carried out at Araromi, Western Region, on twenty mature cacao trees showed that 25 per cent. of the 'die-back' areas in branches $\frac{1}{2}$ in. or more in diameter were infested by termites. These termites were identified as *Neotermes aburiensis* (Sjort) by Mr W. A. Sands of the Colonial Termite Research Unit. It was found that the reproductives began their colony in dead wood, but as the colony increased in size and the dead wood was heavily infected, the living wood was attacked. The damage was often relatively widespread, with borings penetrating 6–8 in. into the living wood. It was observed that where the attack on living wood was extensive the normal distinct claret-coloured zone in the adjacent 'die-back' area was rarely found.

Fungi isolated from capsid lesions, mechanical wounds and 'die-back' areas

In experiments in Ghana certain fungi, particularly *F. decemcellulare* and *Botryodiplodia theobromae*, have commonly been isolated from capsid lesions and 'die-back' areas on cacao trees. The results of similar experiments carried out in Nigeria are presented in Table 29.

TABLE 29

Percentage distribution of fungi in cacao tissues

Site	*No. of isolates*	*Percentage distribution*			
		F. decem-cellulare	*B. theo-bromae*	*Other fungi*	*Sterile*
Occluded capsid lesions ..	250	24	41	28	7
Occluded mechanical lesions ..	100	36	25	23	16
'Die-back' areas	100	24	40	23	13
'Die-back' areas in absence of capsid damage	100	36	25	23	16
Active 'die-back' areas ..	11	27	27	9	37

Longitudinal sections through 'die-back' areas showed that, with the majority of examples examined, the areas could be divided into

three distinctly coloured zones—an outer greyish zone of dead wood from which several fungi, most commonly *B. theobromae*, could be isolated, adjoined by a narrow claret-coloured zone which blackened on exposure, and a narrow water-soaked zone alongside the healthy wood where fungi were apparently absent. In some 'die-back' areas, however, these well-defined zones did not exist. When full zonation occurred *F. decemcellulare* was usually isolated from the claret-coloured zone, while *B. theobromae* was usually isolated from this zone when the water-soaked zone was absent. In some 'die-back' areas the dead wood was not distinctly delineated from the adjacent, probably moribund, tissue. This moribund wood extended up to 12 in. below the dead wood and had an overall diffuse black appearance resulting from black, irregular streaks in the wood. Although no water-soaked zone was visible *F. decemcellulare* was usually isolated from the latter areas.

It has been suggested that the water-soaked zone found in a 'die-back' area is produced by a toxic secretion of the fungus, *F. decemcellulare*, and that the toxin may be produced in culture. Extracts made after the fungus was grown on cassava-dextrose agar gave some wilting of cacao seedlings; but the results were not consistent.

The effect of dry-season irrigation

It is possible that 'die-back' may be associated with lack of soil moisture, particularly during the dry season, and an experiment has been started to test the effect of irrigation on the rate of increase of existing areas of 'die-back', and the rate of initiation of new areas. In a cacao plot of seventy-eight trees, thirty-seven trees were irrigated by hose-pipe at five-day intervals. Each application was equivalent to 1 in. of rain and between the 4th December 1957 and 30th March 1958, twenty-four applications were made. Irrigation has had no effect on the rate of increase of existing areas, and it may be seen from the results given in Table 30 that it has only slightly reduced the initiation of 'die-back'. The irrigation will be continued throughout the wet season.

TABLE 30

Effect of irrigation on 'die-back'

Treatment	*Average number of 'die-back' areas per acre*				
		New areas after			
	At start of trial	1	2	3	4
			months		
Irrigated	10.54	0.83	0.73	0.26	0.51
Not irrigated	10.60	0.60	0.63	0.80	0.81

The effect of fungicidal sprays and pruning

Crowdy has found that *C. rigidiuscula* sporulates most readily on dead wood, and he suggested that control of the fungus may be obtained by pruning dead wood from the trees, and thus reducing the fungal reservoir. This method could be supplemented by fungicidal spraying and both treatments are being tested in an experiment which has been started on a plot of 200 cacao trees. The treatments are:

(*a*) high-volume spray of a 3 per cent. solution of a mercury-synergised copper fungicide, with pruning of dead wood;
(*b*) high-volume spray of a 6 per cent. solution of copper fungicide, with pruning;
(*c*) pruning alone;
(*d*) untreated control.

All the trees were sprayed with *gamma*-BHC to prevent capsid damage. The experiment was started in January 1958 and the results for the first two months are given in Table 31.

TABLE 31

Effect of fungicides and pruning on 'die-back'

Treatment	*Average number of 'die-back' areas in*		
	January	*February*	*March*
Mercury-copper spray with pruning	—	3·5	3·8
Copper spray with pruning ..	—	7·7	2·4
Pruning alone	—	9·1	5·3
Control	5·7	8·6	7·8

Environmental effects on F. DECEMCELLULARE *growth*

A series of experiments have been started to investigate the effect of varying environmental conditions on the growth rate of *F. decemcellulare* in cacao seedlings. Twelve- to eighteen-months-old Amelonado seedlings have been inoculated with spores of the fungus, with sterile inoculation as control, and water levels, degree of defoliation, and shade conditions varied. The average lengths of necrotic tissue revealed in a longitudinal section through the inoculation have been measured on a sample of the seedlings and the results are given in Table 32.

The *F. decemcellulare* inoculations were consistently larger than the sterile ones. The environmental factors had little effect on the size of the sterile inoculations, but inadequate water, no defoliation and shade resulted in an increase of infection due to *F. decemcellulare*. The majority of the sterile inoculations later became infected, and an

TABLE 32

Effect of environment on F. DECEMCELLULARE *growth*

Treatment	*Average length of necrotic tissue (mm.)* *F. decemcellulare inoculation*	*Sterile inoculation*
Watering		
Excess	12.3	2.8
Standard	12.1	3.1
Inadequate	19.2	2.9
Defoliation		
Full	8.8	3.2
Half	7.9	2.9
None	11.2	2.8
Shade		
with 700 ml. water per day ..	13.9	4.2
No shade		
with 700 ml. water per day ..	11.2	3.1
with 1,000 ml. water per day ..	8.9	4.2

analysis showed that 39 per cent. were infected by a *Pestalotia* sp., 39 per cent. by *B. theobromae* Pat., and 18 per cent. by various other fungi, while 4 per cent. remained 'sterile'. Only one sterile inoculation subsequently became infected with *F. decemcellulare*.

OBSERVATIONS ON 'CHLOROSIS', 'LEAFLESS TWIG' AND 'PAINT BRUSH' DISEASES OF CACAO IN THE BRITISH CAMEROONS

(C. K. H. Martini)

'CHLOROSIS'

Grafting experiments by previous workers to test whether 'chlorosis' was a virus disease gave negative results, possibly because the tests were done at Tafo and Ibadan and a virus might have been inactivated in transit. Similar experiments were therefore carried out in the Cameroons. Six seedlings that had been grafted with patches taken from trees showing 'chlorosis' symptoms flushed twice during two months of observation but no symptoms were produced.

'LEAFLESS TWIG'

Leafless twigs, which are common on old cacao in the Cameroons, began flushing in early November and most of the trees looked healthy by early December. Twigs usually lose their leaves sometime between January and the beginning of the rainy season, but very few of them die. Where 'die-back' was found it was usually associated with capsid damage. As trees under shade usually have good canopies and there was no evidence to indicate that 'leafless twig' is caused by a parasite,

it is possible that this condition may be associated with lack of shade. It was noticed, however, that trees growing under shade suffer from capsid damage, 'die-back' and termite infestation to the same extent as in the Western Region of Nigeria.

'PAINT BRUSH'

This condition is usually associated with seedlings up to the age of three years but it occurs also on chupons of old trees and on buds of branches of dying trees. Several hundred seedlings in four plantations were observed at regular intervals from mid-October to early-December. During this time the percentage of seedlings showing the symptoms decreased from about 75 per cent. to 5 per cent. or less and almost all the seedlings which had shown the symptoms had flushed at least once by early December. Attempts to isolate a pathogen have failed and it has not been possible to reproduce the symptoms by grafts from affected to symptomless seedlings. No parasitic nematodes were found on affected seedlings or in the surrounding soil. 'Paint brush' occurs to the same extent in unsprayed and regularly sprayed plantations and did not appear to be associated with insect attack. The mites which are occasionally found are believed to be associated with rotting tissue. Fungi were obtained very irregularly from buds kept in moist chambers. However, it is possible that a fungus could kill the young flush leaves, but that its isolation may be possible over a very limited period of a day or two, perhaps when the leaves are just showing symptoms.

Spraying with a 2.5 per cent. borax solution had no effect on the symptoms. Records taken in two NPK fertilizer experiments gave no indication that the condition is influenced by any of the nutrients applied.

Although the cause of 'paint brush' is still unknown it is possible to suggest preventive measures which could reduce its incidence. Amazon cacao varieties appear to suffer less than local Trinitario varieties, and poor seedlings and seedlings that are damaged at planting are more likely to develop 'paint-brush'. Unshaded and insufficiently shaded seedlings are also more likely to become affected. Psyllids and the larvae of various Lepidoptera tend to aggravate the condition, and spraying may facilitate recovery of damaged or weakened buds.

CAPSID STUDIES

(R. G. Donald)

CHEMICAL CONTROL OF CACAO CAPSIDS

The trials using BHC against capsids on sixty-three 5-acre plots

were handed over to the Department of Agriculture, Western Region, Nigeria, which has continued to run them, with some modifications to the spraying programme, throughout the year. A comparison of the yields obtained from July 1956 to June 1957 with those from July 1957 to December 1957 has indicated that where effective control of capsid damage has been achieved production has increased considerably. More pods were harvested during the later period from trees which, at the beginning of the experiment, had only a half or less of the normal canopy. The yields from trees which had lost about a quarter of the canopy were slightly lower in the second period while trees with a more or less complete canopy have given approximately 56 per cent. of the previous year's yield. The decline in yield from the less severely damaged trees is due to the fact that the comparison is being made of the crop produced in an incomplete year, during which average production throughout the Region has been low, with that for a full year during which Nigerian cocoa production reached a record figure. It has been estimated that the crop for the present season will probably be between 60 and 70 per cent of the 1956–57 crop, and if this is so it would appear that trees which had previously suffered any noticeable loss of canopy have all benefited from spraying.

Severely damaged trees showed the highest percentage increase in yield, but the increase in terms of pods per tree was greatest from trees on which about half the canopy was present at the beginning of the trial. It is estimated that on an average cacao farm in the Western Region of Nigeria and in a normal season, control of capsids should lead to an increase of at least two and a half to three pods per tree, or approximately 100 lb. of dry beans per acre, in the following year for an outlay of about £4 per acre.

MEALYBUG STUDIES

(R. G. Donald)

Counts of mealybugs on two contiguous plots of cacao on Moor Plantation have been undertaken during the latter part of the year. One plot had been abandoned in 1951 and the trees had become overgrown with creepers and secondary bush, whereas the other plot had been kept free from tall weeds. Many trees in both plots had been severely damaged by capsids, 'die-back' and drought and only trees with a reasonably full canopy were examined.

Ants of the genus *Crematogaster* were abundant on only a few trees in the abandoned plot, where they attended most colonies of *Planococcus kenyae* (Le P.), *P. citri* (Risso) and *Pseudococcus njalensis* Laing. On the remainder of this plot, and on the weeded plot, less than

10 per cent. of colonies were attended by ants, almost half of these (4.5 per cent.) being attended by species other than *Crematogaster* spp.

All trees in both plots were found to be infested with from two to seven of the nine different species of mealybugs encountered. The mean number of colonies per tree in each plot was the same, namely forty, the mean colony size being slightly higher on the abandoned plot (4.5 bugs/colony) than on the cleared one (4.0 bugs/colony). This difference was due to the presence of a greater number of nymphs on the former.

The most abundant species of mealybugs on both plots were *P. kenyae*, *Ferrisiana virgata* (Ckll.) and *P. citri*, in that order. *Pseudococcus* sp. nr. *proteae* (Hall) was more common on the abandoned plot than on the weeded one, accounting for 4.5 per cent. and 1.9 per cent. of the total mealybugs in the respective plots. *P. njalensis* was absent from the weeded plot but was relatively abundant on the abandoned plot (6 per cent.) where it was almost entirely confined to the trees on which Crematogasterine ants were numerous. *Pseudococcus concavocerarii* James was found to account for 1.5 per cent. of the mealybugs on the weeded plot, but was very rare on the abandoned plot. *Pseudococcus bukobensis* Laing, *Pseudococcus* sp. nr. *gahani* Green, and an unidentified species probably of the genus *Planococcus* Ferris, were present in small numbers on both plots.

F. virgata increased markedly in numbers when a flush of new leaves was produced after the early rains. No other seasonal variations were noted.

STUDIES ON BORERS

(R. G. Donald)

SHOT-HOLE BORERS

Reports of damage by shot-hole borers (Coleoptera: Scolytidae) were received from several localities during the dry season. Most of the attacks were confined to seedlings in their first or second year in the field, though at one locality fan-branches of four-year-old trees were attacked. Dead and wilting seedlings were collected from the Department of Agriculture's Farm at Akure, in the Western Region of Nigeria, and it was found that heavy infestations occurred only after wilting, probably caused by inadequate water supply, had become severe. Of the ninety-five adult beetles found in sixty seedlings eighty-six were in twenty seedlings which were either entirely dead or had all the leaves dead but some green wood remaining. Seven were in twenty seedlings in which most of the leaves were dead but a few were still green and only two were found in the remaining twenty seedlings which were showing only slight signs of wilting.

Stephanoderes spp. were more numerous than *Poecilips confusus* Egg. and *Xyleborus morstatti* Hag. and were found to have entered the stems mainly through leaf scars or withered leaf petioles which had not abscissed. *P. confusus* and *X. morstatti* frequently entered at such sites but occasionally galleries were found to begin in the internodes. The wood surrounding a few empty galleries which were found in the living portions of the stems of some seedlings showed signs of discoloration and *Botryodiplodia theobromae* and *Fusarium decemcellulare* were isolated from these areas by the mycologist.

OTHER BORERS

A severe attack by *Apate monacha* Fab. (Coleoptera: Bostrychidae) was found at Apoje in Ijebu Province. About 70 per cent. of the larger seedlings in an area of about a quarter of an acre of three- to four-year-old cacao were affected, but only one of the younger plants which had been used to fill vacancies during the past two seasons was seen to be attacked. The attack was most severe on the biggest plants, one of which had seventeen entry holes in the trunk and two at the base of the branches immediately above the jorquette. Many of the galleries were empty but several contained either one or two adult beetles. The area in question had had much of the shade removed during the last few months of the previous wet season and it is considered that this may have contributed to rendering the plants susceptible to attack. Two other smaller areas of damage by *Apate* have since been reported from Apoje.

Both at Apoje and Akure small seedlings were found which had been attacked by weevils near ground level. The damage was done by larvae which bore in the stems, killing the seedlings. Several larvae may be present in one plant and pupation takes place within the affected stems.

One specimen of a species of Anthribidae was reared from a larva attacking a seedling at Apoje. The damage was similar to that done by the weevils mentioned above.

WEST AFRICAN COCOA

BALANCE SHEET AS

LIABILITIES

	£	s.	d.	£	s.	d.
SURPLUS ACCOUNT				2,674,418	2	10
DEPRECIATION RESERVE FUND—						
Motor Vehicles	9,039	10	6			
General Equipment	4,351	16	0			
				13,391	6	6
SUNDRY CREDITORS	6,113	10	4			
ACCRUED CHARGES	4,074	4	7			
				10,187	14	11

(Sgd.) J. LAMB, *Director.*

(Sgd.) HYWEL LL. PUGH, *Secretary.*

£2,697,997 4 3

We have audited the above Balance Sheet of the West African Cocoa Resear explanations that we have required. In our opinion and subject to our Report of even da of the Institute as at 31st March, 1958, according to the best of our information and t

ACCRA,
20th September, 1958.

RESEARCH INSTITUTE

AT 31st MARCH 1958

ASSETS

	£ s. d.	£ s. d.
BUILDINGS—		
Cost to 31st March, 1957	340,986 6 1	
Additions during year	55,201 9 1	
	396,187 15 2	
Less Amounts written off	396,187 15 2	
FURNITURE AND EQUIPMENT—		
Cost to 31st March, 1957	34,854 17 0	
Additions during year	17,504 3 2	
	52,359 0 2	
Less Amounts written off	52,359 0 2	
DEPRECIATION RESERVE FUND—		
Post Office Savings Bank—Deposit	4,053 3 3	
Bank of West Africa Limited—Deposit ..	3,199 2 11	
		7,252 6 2
SUNDRY DEBTORS—		
Staff Advances	19,390 14 6	
Western Nigerian Government	253 17 3	
Eastern Nigerian Government	372 19 8	
British Cameroons Government	615 3 4	
WAITS	215 0 0	
Miscellaneous Debtors	1,736 5 2	
Deposits and Prepayments	4,053 19 8	
		26,637 19 7
STORES AT COST—		
Timber	938 14 0	
Maintenance	6,768 11 4	
		7,707 5 4
INVESTMENTS—at book value (Market value at 31.3.58, £2,163,310 1s. 1d.)		2,595,664 18 3
CASH, BANK BALANCES AND FUNDS WITH CROWN AGENTS—		
Cash on Hand—Tafo	200 0 0	
—Ibadan	20 0 0	
Bank of West Africa Limited—Tafo	24,203 16 2	
—Ibadan ..	2,520 10 9	
Crown Agents—Joint Miscellaneous Fund ..	31,000 0 0	
—Endowment Fund	2,650 0 0	
—Current Account	140 8 0	
		60,734 14 11
		£2,697,997 4 3

istitute with the books and vouchers of the Institute and have obtained all the information and tached hereto, this Balance Sheet sets forth a true and correct view of the financial position planations given to us and as shown by the Books of the Institute.

(Sgd.) CASSLETON ELLIOTT & CO.
Auditors.

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